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The availability and geographic location of open-source food composition data used to estimate micronutrient intakes in sub-Saharan Africa: A scoping review

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ABSTRACT

Background: Estimates of dietary micronutrient intakes rely on food composition data. The nutrient composition of foods varies spatially with potentially large effects on dietary micronutrient intakes. This review assessed the availability and geographic origin of five minerals (calcium, iron, iodine, selenium and zinc) in publicly available food composition tables/databases (FCTs) for use in sub-Saharan Africa (SSA).

Methods: A scoping review was conducted following PRISMA guidelines, in which four databases (MEDLINE, Embase, Global Health and Africa Wide Information) and four online resources were searched to identify published FCTs for use in SSA. Metadata were reviewed to identify the geographic origin of composition values for selected foods.

Results: Nineteen publicly available FCTs were identified, with the highest geographic coverage in Eastern Africa (45% of countries) and lowest coverage in Central Africa (12% of countries). Iodine and selenium were reported in four and six FCTs, respectively, while iron and calcium were included in ≥ 18 FCTs. More than 60% of nutrient values were borrowed from other FCTs. The geographic origin of 22% of mineral values were documented.

Conclusions: Limited local food composition analytical data is available, for estimating mineral intakes of SSA populations, with poor documentation of the data sources and the geographic origins of samples. New data structures and improved metadata are required to capture and report geographic information in publicly available FCTs, and to accommodate a new generation of spatially-resolved food composition data.

1. Introduction

Globally, over two billion people are affected by one or more micronutrient deficiencies (MNDs). The prevalence of MNDs and associated disease burdens is highest in low- and middle-income countries, including sub-Saharan Africa (Arsenault et al., 2015; Beal et al., 2017; Joy et al., 2014; Schmidhuber et al., 2018; Smith et al., 2016; Wessells et al., 2012; White et al., 2021). Inadequate dietary micronutrient intake is one of the factors contributing to the high prevalence of MNDs. Hence, reliable data on the micronutrient composition of foods, food consumption patterns, dietary intakes of micronutrients and when available, the prevalence of MNDs are required for designing, prioritising, monitoring, and evaluating programmes and policies to alleviate micronutrient deficiencies, including biofortification and food fortification (Neufeld et al., 2017; Popkin et al., 2020).

In recent years, several groups have compiled regional and national food composition tables and databases (FCTs) and nutrient conversion tables (NCTs) (see Table 1: Food composition terms and definitions) to assess the dietary micronutrient intakes of populations in sub-Saharan Africa (e.g., FAO/INFOODS Food Composition Table for Western

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Abbreviations: FCTs, Food Composition Tables and Databases; NCTs, Nutrient Conversion Tables; MNDs, Micronutrient Deficiencies.

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Table 1
Food composition terms and definitions.

Term	Definition	Reference
Food composition tables and databases (FCTs)	FCTs are lists of foods, in (printed) tables and/or database formats, that provide data on the content of energy, nutrients and other food components. Ideally the selection of foods included would cover those foods that are relevant and highly consumed by the population for which the FCTs are intended for.	Adapted from Greenfield and Southgate (2003).
Type of (food composition) data	FCTs are normally compiled using combined methods. Some values may be obtained form direct chemical analysis of foods (primary data), others by compilation from literature screening (secondary data), or borrowing from other FCTs	Adapted from Greenfield and Southgate (2003).
Primary analytical data	This type of value is the result of chemical analysis of food carried out specifically to populate a FCT.	Adapted from Greenfield and Southgate (2003).
Secondary analytical data	This type of value is taken from published literature, thesis, unpublished laboratory reports etc. that reported chemical analysis of foods.	Adapted from Greenfield and Southgate (2003).
Borrowed data	This type of value is taken from other FCTs.	Adapted from Greenfield and Southgate (2003).
Source of the data	It refers to where the data were obtained from (e.g., a study published in literature, or contractors' analysis).	Adapted from Greenfield and Southgate (2003) and Pennington (2008) .
Nutrient Conversion Tables (NCTs)	A nutrient conversion Table (NCT) is a collection of data on the nutrient content of foods reported as supplied, consumed and/or acquired in a specific survey, e.g. a household consumption and expenditure survey. Therefore, the NCT is study specific, and it is based on compiled information from national and/or regional food composition tables and databases (FCTs/FCDBs) following food matching guidelines (e.g., FAO/INFOODS). It is needed to assess the dietary energy and nutrient supply and/or (apparent) consumption of the survey's population.	Developed for this study, based on Moltedo et al. (2018), and personal communication with the author (A.M).

Africa (2019), Malawian Food Composition Table (2019), Kenya Food Composition Tables (2018), etc.). While considerable efforts have been made to compile high quality and comprehensive food composition data, limitations remain. For example, nutrient values are typically borrowed from the FCTs of other countries when analysed data from in-country food samples are not available. These borrowed values may be inaccurate due to spatial variation in crop composition, as well as differences in food fortification policies and local food preparation and cooking practices (Ene-Obong et al., 2019; van Graan et al., 2019; Pennington et al., 2007). Furthermore, the nutrient composition values of each food item, (e.g., iron in wheat flour, or zinc in maize flour), are typically represented by a single data point, which may mask important subnational variation, including spatially-structured variation in the nutrient content of local foods (Gashu et al., 2021). Additionally, re-use of data may propagate nutrient composition values which were quantified using obsolete analytical methods and equipment, or values with inadequate descriptions and/or reporting of nutrients, foods and recipes (Traka et al., 2020). Finally, in some FCTs and for some nutrients, there can be multiple missing values. For example, in the Food Composition Table for use in Africa, which is still used as a source of mineral values, only 50% of the 1624 food items have data on mineral composition (Woot-Tsuen et al., 1968). This paucity of data and the lack of transparency in nutrient composition metadata has major implications for the ability to accurately estimate the prevalence of the population at risk of inadequate dietary micronutrient intakes.

The nutrient composition of crops vary spatially due to factors including soil type and climate, and this variation can be nutritionally relevant. For some minerals, spatial variation in staple crop composition is one of the main drivers of sub-national variation in population status (Belay et al., 2020; Botoman et al., 2022; Gashu et al., 2021; Kihara et al., 2020; Phiri et al., 2019). This is particularly true in contexts where food systems are localised and diets are dominated by locally produced staple crops (e.g., maize, rice, *teff,* cassava), which is the case for many people living in sub-Saharan African countries (Joy et al., 2015b; Ryckman et al., 2021). When foods are produced and sourced locally, their nutrient content will partly depend on local agri-food practices (e.g., use of inputs, milling, fermentation, storage, etc.) and environmental factors (e.g., soil type, soil pH, precipitation, etc.). Several studies in sub-Saharan Africa have reported spatial variability in the mineral contents of various staple crops. For example, Gashu and colleagues (2021) reported nutritionally important geospatial variation in the content of calcium (Ca), iron (Fe), selenium (Se), and zinc (Zn) in *teff* and wheat grains in Ethiopia and in maize grain in Malawi. Smaller studies have investigated the spatial variation in other countries in the region, yielding similar conclusions (Joy et al., 2015a;b; Manzeke et al., 2019; Watts et al., 2019; Wood et al., 2018). These studies highlight the importance of locally-sampled food composition data, including the five minerals included in this review: Ca, Fe, iodine (I), Se and Zn, for which spatial variation in their concentration may influence the estimates of inadequate and/or excessive intakes resulting in important health implications. Close monitoring of dietary mineral intakes (including from drinking water) and fortification programs in the region is vital to identify populations at risk of inadequate and/or excessive intakes. Thus, to accurately quantify and understand the prevalence and aetiology of mineral deficiencies, spatially structured food composition data are needed to estimate the intake of minerals including Ca, Fe, I, Se and Zn. The construction of these FCTs/NCTs should reflect local food systems and spatial variability at scales relevant to the context (Botoman et al., 2022; Gashu et al., 2021; Joy et al., 2015a,b; Ligowe et al., 2020).

Information on the type of data populating FCTs/NCTs and their geographic origin are necessary to assess the influence of spatial variation on mineral intake estimations for populations consuming locally produced foods. That information is also essential to evaluate modelling outputs that use FCTs/NCTs as underlying data, however it is currently unavailable and/or difficult to access. Hence, this scoping review aimed to capture the current status of freely available FCTs/NCTs used or available for use in estimating dietary intakes of Ca, Fe, I, Se and Zn in sub-Saharan Africa, and to identify data gaps and limitations. Specifically, the data and metadata available to assess spatial variation in the mineral content of foods were evaluated.

2. Materials and methods

2.1. Research questions

The objective of this review was to assess the availability of open-sourced and geographically-relevant FCTs/ NCTs to estimate dietary intakes of Ca, Fe, I, Se, and Zn in sub-Saharan Africa. These minerals were selected for their public health relevance given the widespread prevalence of inadequate dietary supplies in sub-Saharan Africa (Joy et al., 2014). There is also evidence of strong spatial variation in the mineral contents of staple foods, which may result in spatial variation in dietary adequacy given the localised nature of food systems, particularly for rural, low-income households (Gashu et al., 2021).

The primary research question was: What FCTs/ NCTs are freely available in the public domain for use in estimating dietary intakes of Ca, Fe, I, Se, and Zn in sub-Saharan Africa?

The secondary research questions were:

a. What is the geographic scope of the FCTs/ NCTs available to estimate dietary intakes of Ca, Fe, I, Se and Zn in sub-Saharan Africa?
b. What percentage of mineral composition data are missing for selected food items in FCTs/ NCTs available for use in sub-Saharan Africa?
c. For available data, what information is reported on the geographic location of food samples, and is it reported only at the food item level (e.g. maize flour) or at food item-micronutrient level (e.g. Zn in maize flour)?

2.2. Study design and protocol

A study protocol was developed following Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) extension for protocols (Moher et al., 2015). A full description of the method can be found in the study protocol which was registered with the Open Science Framework (OSF) (Segovia de la Revilla et al., 2022), hence only a brief description is provided below.

A scoping review method was used, which was informed by the PRISMA extension for scoping reviews (PRISMA-ScR) as guidelines (Tricco et al., 2018). FCTs and NCTs that provide data on Ca, Fe, I, Se and Zn concentration in foods for any geographic location within sub-Saharan Africa were identified. Mineral values, data documentation and metadata available were extracted for a selection of food items in each FCT/ NCT, including information on the geographic location of each mineral value per food item. The food items selected were those that matched the Food and Agriculture Organization of the United Nations (FAO) Food Balance Sheet (FBS) ([dataset] FAO, 2010) food categories providing a high percentage of energy and/or minerals in the food supply of sub-Saharan Africa countries, as described in detail in the study protocol (Section 4.1: "Food items included for the secondary outcomes" in Segovia de la Revilla et al., 2022) and summarised below in the Section 2.6.

2.3. Eligibility criteria

Stand-alone FCTs developed for sub-Saharan African countries and/ or regions were included, regardless of whether they had previously been used in a published study. In addition, studies that reported the use of FCTs/ NCTs to estimate dietary intakes of at least one of the minerals of interest (Ca, Fe, I, Se and Zn) by human subjects (with no age or gender restriction) in sub-Saharan Africa, including both experimental and non-experimental study designs (e.g., cohort, case-control, cross-sectional, ecological, modelling), were reviewed. From these studies, the sources of food composition data used in the study were identified and the relevant FCTs/ NCTs were retrieved. When multiple versions of a specific FCT were available, only the most recent version was reviewed, on the assumption that an update is based on the most recent and accurate information. Moreover, only those that were free to access and in digital format were included.

2.4. Information sources and search strategies

In this review four online databases were searched: MEDLINE, Embase, Global Health and Africa Wide Information. Keywords and subject headings, when available, were used to cover all terms related to food and nutritional composition data. In addition, "Expert Search" (i.e., "ALL countries in sub-Saharan Africa, Medline. List from World Bank, June 2019", "ALL sub-Saharan Africa Countries, Embase. List from World Bank, June 2019") were used to ensure that all countries in sub-Saharan Africa were included. No limits, search filters or restrictions were applied in any of the databases. In addition, four online resources were included in the search, which were: FAO/INFOODS: Africa (INFOODS, 2022), LanguaL (LanguaL, 2022), Nutritool (Nutritools, 2018), World Nutrient Databases for Dietary Studies (WNDDS) (WNDDS, 2022). The search strategy was designed following PRISMA guidelines (Moher et al., 2015), and the PRISMA extension for Reporting Literature Search in Systematic Reviews (PRISMA-S) (Rethlefsen et al., 2021). It was published together with the protocol in OSF (Segovia de la Revilla et al., 2022).

2.5. Study selection process

Screening and removal of duplicates was carried out using Mendeley (v.1.19.8). The screening of the studies was done in two steps: first, titles and abstracts were screened and second, from those selected in step one and retrieved, full text studies were screened. The reason(s) for exclusion were recorded in a spreadsheet (R1: excluded due to study type, R2: excluded due to nutrient(s) reported, R3: excluded due to location/scope of the study). Similarly, information on the retrieval of full text studies ("Yes"/"No") and the reason for failure (R1: not electronically available, R2: not found, R3: not accessible) were documented. Then, the food composition information was extracted from each study which included: FCT/ NCT name, authors, geographic location, and date of publication. Similar steps were carried out for stand-alone FCTs extracted from grey literature and websites. For FCTs that were not available online, a request was sent to the authors. Details on the data and the screening process are reported in the supplementary materials.

2.6. Data items and data abstraction process

The primary outcome was a list of the most recent, free to access and available FCTs/ NCTs for use in sub-Saharan Africa that reported at least one of the five minerals of interest (Ca, Fe, I, Se, and Zn), and the geographic scope of those datasets.

The secondary outcomes were the availability of mineral nutrient values, the source of information, type of data (See "Terms and definitions" in Table 1) and the geographic origin of each mineral value for a selection of foods. Data extracted to inform the secondary outcomes included the pre-defined subset of food items per FCT/ NCT. This subset of food items was selected based on FBS categories (e.g., maize and products, rice and products) and their contribution to the energy and/or the supply of the five minerals of interest in sub-Saharan Africa, as described elsewhere (Segovia de la Revilla, et al., 2022).

2.7. Synthesis of results

The list of all the FCTs/ NCTs for use in sub-Saharan Africa were collated in a spreadsheet. Similarly, the list of food items from each FCT/ NCT, their mineral content per 100 g and documentation, including type and source of data and geographic location, were extracted. Both data collection forms were piloted by extracting the data from three FCTs. More details regarding the data extraction and variables extracted are reported in Section 4 of the protocol (Segovia de la Revilla et al., 2022).

Data processing (except screening of the studies and de-duplication of the results), which included: compilation of the results from the screening process (i.e., FCTs/NCTs found in databases and in online databases and in resources), loading the data (FCTs/NCTs), extraction of the mineral values and the source of information per food item, harmonisation of the variable names, summary statistics (i.e., counts, mean, median, minimum and maximum) and visualisation (i.e., boxplots, histograms) were performed using R (R Core Team, 2020) and RStudio (Rstudio Team, 2020) and the code is available in GitHub.

3. Results

3.1. Study flow

The screening process is summarised in the PRISMA 2020 flow diagram (Fig. 1), and screening records can be found in supplementary materials (S.M.1). In summary, from the four online databases searched, 921 studies were identified for screening, of which 243 studies were selected for full text screening. Of these, 70 studies were unavailable, and 173 were reviewed for eligibility. Ultimately, from the electronic databases, 109 studies were included in the review and from those studies, 50 FCTs/ NCTs were identified that had been used to estimate mineral intakes of populations in sub-Saharan Africa.

From the four online resources (i.e., websites that hosted FCTs or FCT listings), 44 unique stand-alone FCTs were identified for sub-Saharan Africa (Fig. 1). No FCTs were retrieved from WNDDS as data were not accessible (that is, the underlying data displayed in the dashboard were unavailable) and all the FCTs displayed in the dashboard had been included.

After removal of duplicates, 71 unique FCTs/ NCTs were identified for use in estimating dietary intakes of Ca, Fe, I, Se and Zn in sub-Saharan Africa. From these, 44 were excluded based on the eligibility criteria of selecting the most recent version for each geographic area (i.e., country, region), while eight were excluded based on accessibility (Suppl. Tables 1–2).

3.2. Food composition data for use in sub-Saharan Africa

In total, 19 FCTs/ NCTs for use in sub-Saharan Africa were identified based on our criteria which dated from 1988 to 2021 (Table 2). In Fig. 2, the geographic scope of the FCTs/NCTs included in the review are presented. The majority of the FCTs/ NCTs included were national FCTs/ NCTs (n = 13), of which the highest coverage was provided for Eastern Africa (n = 7; 37% of 19 Eastern African countries), followed by Western Africa (n = 4; 23% of 17 Western African countries). For Southern and Central regions only one FCT and one NCT, in each region respectively, were included in this review (representing 20% of five Southern African and 10% of 10 Central African countries, respectively).

The widest geographic area covered by the FCTs/NCTs reviewed was the regional Africa NCT (Joy et al., 2014) which provided food composition data on the five minerals for three sub-Saharan African regions (Eastern, Western, and Southern regions), whereas the smallest geographic areas covered were the two sub-national NCTs for Kenya, Tanzania (Watts et al., 2019a,b) and two sub-national FCTs for Uganda

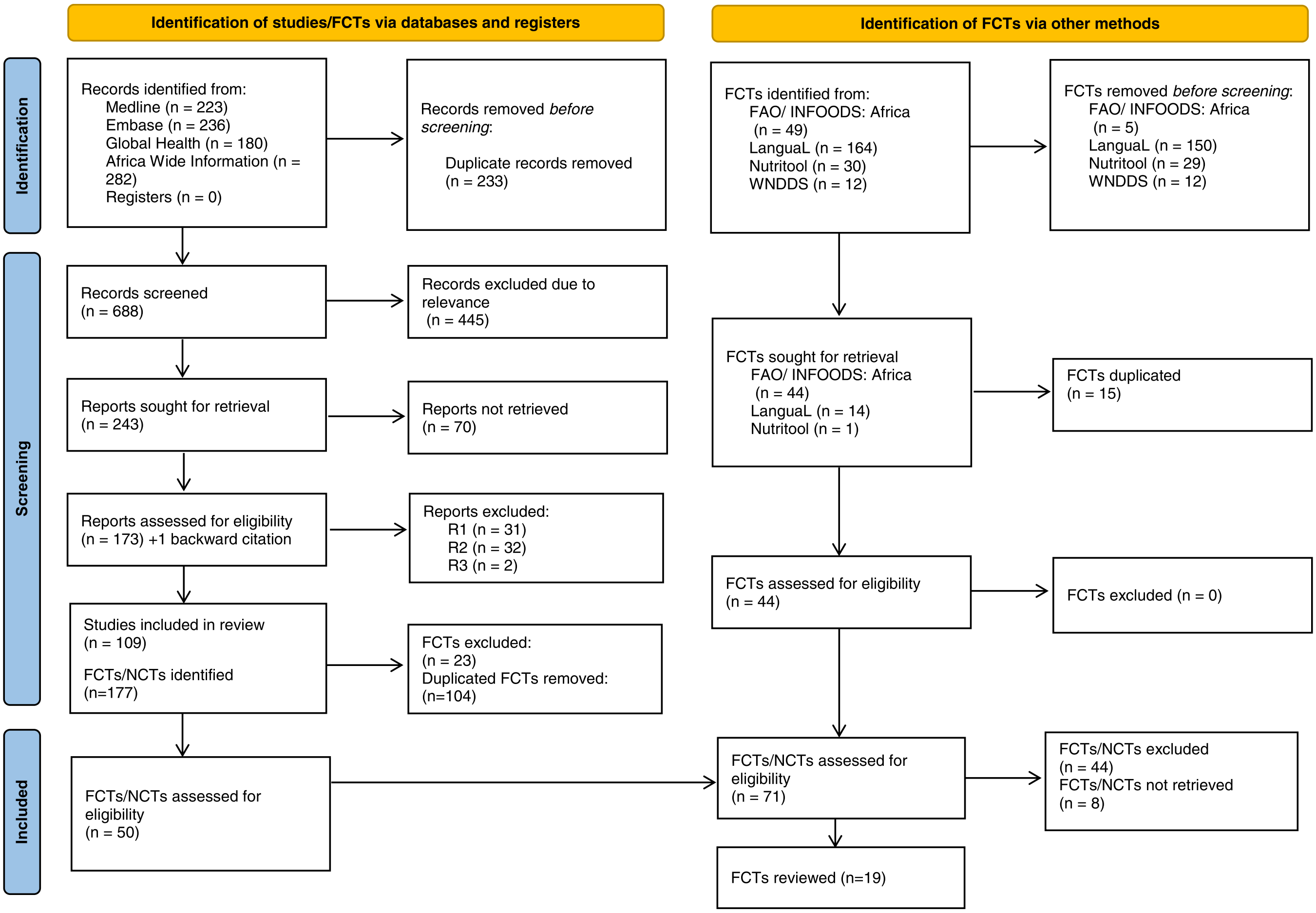

Fig. 1. *FCTs: Food Composition Tables and Databases, NCTs: Nutrient Conversion Tables, WNDDS: World Nutrient Databases for Dietary Studies.* Footnote: R1: excluded due to study type (e.g., not using or reporting FCT for dietary assessment), R2: excluded due to nutrient(s) reported, R3: excluded due to location/scope of the study. PRISMA – Flow diagram adapted from Page et al., 2021.

Table 2
List of food composition tables and databases (FCTs) and nutrient conversion tables (NCTs) included in the review and their characteristics.

Food composition table name	*Year of publication*	*Food Composition Type*	*Food Composition Format*	*Type of data*	*Language*	*Geographic Scope*	*Mineral reported*	*Reporting level*	*Food items reviewed*	*Reference*
Eastern Africa FCT, 1988	1988	Table	pdf	Multiple source (analytical, borrowed, calculated)	English	East Africa	Ca, Fe,	Mineral	18% (26/146)	West et al. (1988)
Zimbabwe FCT, 1989	1989	Table	pdf	Borrowed from FCTs, analytical values from literature	English	Zimbabwe	Ca, Fe,	Food Composition	13% (17/135)	Chitsiku (1989)
Lesotho FCT, 2006	2006	Table/ database	pdf/xlsx	Borrowed from FCTs, analytical values from literature	English	Lesotho	Ca, Fe, Se, Zn	Item	6% (17/294)	Lephole et al. (2006)
Tanzania FCT, 2008	2008	Table/ database	pdf/xlsx	Borrowed values from FCTs	English	Tanzania	Ca, Fe, Zn	Food Composition	7% (27/400)	Lukmanji et al. (2008)
Zambia FCT, 2009	2009	Table	pdf	Borrowed from FCTs, analytical values from literature	English	Zambia	Ca, Fe, Zn	Item	12% (32/272)	NFNC (2009)
The Gambia FCT, 2011	2011	Table	pdf	Multiple source (analytical, borrowed, calculated)	English, but food names are mainly in Mandinka	Kiang District, Gambia	Ca, Fe, Zn	Mineral	2% (10/470)	Prynne and Paul (2011)
Mozambique FCT, 2011	2011	Table/ database	pdf/xlsx	Multiple source (analytical, borrowed, calculated)	English	Mozambique	Ca, Fe, Zn	Mineral	10% (20/205)	Korkalo et al. (2011)
Central and Eastern Uganda FCT, 2012	2012	Table/ database	pdf/xlsx	Borrowed values from FCTs	English	Central and Eastern Uganda	Ca, Fe, Zn	Item	4% (27/727)	Hotz et al. (2012)
Cameroon NCT, 2013	2013	Table	pdf	Analytical from literature	English	Cameroon	Ca, Fe, Se, Zn	Item	3% (4/117)	Kouebou et al. (2013)
Regional Africa NCT, 2014	2014	Database	xlsx	Borrowed values from FCT and analytical values from publication	English	Western, Eastern and Southern Africa	Ca, Fe, I, Se, Zn	Mineral	24% (66/276)	Joy et al., 2014
Mali FCT, 2015	2015	Table	pdf	Borrowed from FCTs, and analytical values from publications (Zn)	English	Mali	Ca, Fe, Zn	Mineral	40% (10/25)	Koréissi-Dembélé et al. (2017); Koreissi (2015)
Kenya FCT, 2018	2018	Table/ database	pdf/xlsx	Multiple sources (analytical, borrowed, calculated)	English	Kenya	Ca, Fe, Se, Zn	Item	6% (35/663)	[dataset] FAO/Government of Kenya, 2018
Western Kenya NCT, 2019	2019	Database	xlsx	Analytical values from publications, and borrowed from FCTs	English	Western Kenya	Ca, Fe, I, Se, Zn	Mineral	22% (20/92)	Watts et al. (2019b)
Kilimanjaro Tanzania NCT, 2019	2019	Database	xlsx	Analytical values from publications, and borrowed from FCTs	English	Kilimanjaro, Tanzania	Ca, Fe, I, Se, Zn	Mineral	25% (23/92)	Watts et al., (2019a)
Malawi FCT, 2019	2019	Table	pdf	multiple sources (analytical, borrowed, calculated)	English	Malawi	Ca, Fe, I, Se, Zn	Item	8% (25/316)	van Graan et al. (2019)

(*continued on next page*)

Table 2 (*continued*)

Food composition table name	*Year of publication*	*Food Composition Type*	*Food Composition Format*	*Type of data*	*Language*	*Geographic Scope*	*Mineral reported*	*Reporting level*	*Food items reviewed*	*Reference*
Nigeria FCT, 2019	2019	Database	xlsx/ website	Borrowed from FCTs, and analytical values from publications	English	Nigeria	Ca, Fe, Zn	Item	10% (28/ 281)	Nigeria Food Database (2019)
Senegal NCT, 2019	2019	Table	pdf	Borrowed values from FCTs	English	Senegal	Fe, I, Zn	Mineral	25% (15/60)	Yoo et al. (2019)
Western Africa FCT, 2019	2019	Table/ database	pdf/xlsx	Multiple sources (analytical, borrowed, calculated)	English, French	Western Africa	Ca, Fe, Zn	Item	5% (56/ 1028)	Vincent et al. (2020)
Southern and Western Uganda FCT, 2021	2021	Table/ database	pdf/xlsx	Borrowed from FCTs, and product labelling	English	Southern Western Uganda	Ca, Fe, Zn	Food Composition	0	Scarpa et al. (2021)

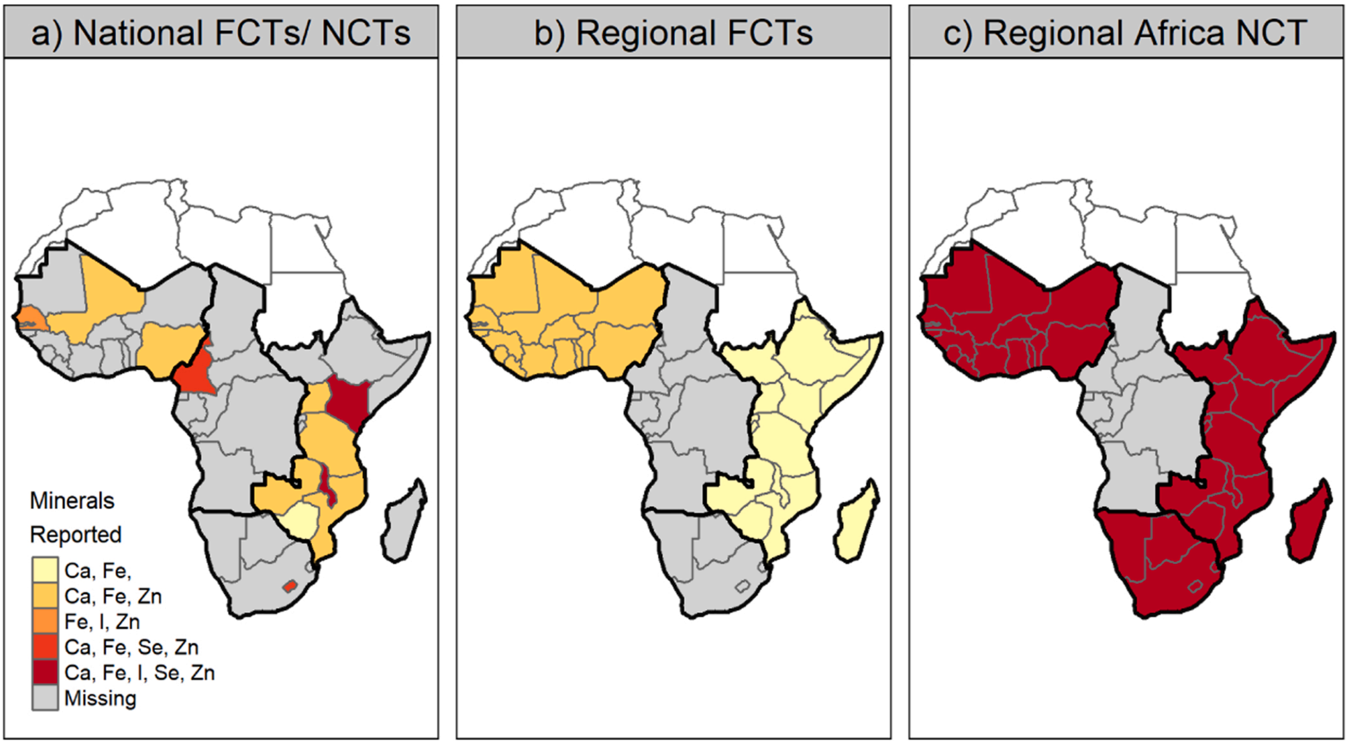

Fig. 2. Geographic scope and the minerals of interest reported in each of the FCTs/ NCTs included in the review. Panel a) shows the national food composition tables and databases/nutrient conversion tables (FCTs/NCTs) and the minerals of interest that were included. Panel b) shows the regional FCTs and the mineral of interest that were included, and panel c) shows the regional Africa NCT coverage and the mineral included.

(Hotz et al., 2012; Scarpa et al., 2021). Two regional FCTs provided information for Western Africa (Vincent et al., 2020) and Eastern Africa (West et al., 1988) (see Fig. 2.b).

The mineral nutrients that were most often included were Fe, which was reported in all the FCTs/ NCTs reviewed, Ca (reported in 18 of 19 FCTs/ NCTs) and Zn (reported in 17 FCTs/ NCTs). Conversely, I and Se were included in only five and seven FCTs/ NCTs, respectively (Table 2).

Regarding the source of information (i.e., source information for the mineral values, see Table 1), three FCTs reported it at the FCT level, eight FCTs/ NCTs reported it at food item level (of which four reported only one reference), and seven FCTs/ NCTs reported it at the mineral value level (i.e., food item nutrient level) (Table 3). Source information was only traceable, where it was reported, at the food item mineral level, or at the food item level when only one source was reported.

All the FCTs/ NCTs reviewed, except the Cameroon NCT, 2013 (Kouebou et al., 2013), reported the use of other FCTs in the compilation of the mineral data (borrowed values), whereas six FCTs and two NCTs reported the use of chemical analysis to populate the mineral values for at least a selection of foods (analytical primary values). When data were borrowed, and where it was possible to trace back to the original source, it was apparent that some FCTs/NCTs were drawing on analyses conducted many decades ago, with a heavy reliance on the Food Composition Table for use in Africa (Woot-Tsuen et al., 1968).

On average, 27 ± 17 food items per FCT/ NCT (range:0–72) were selected for assessing the percentage of missing mineral values (Section 3.3) and when mineral values were available, to identify the geographic location of the sample used to generate the mineral values (Section 3.5). The highest number of food items were extracted from the regional

Table 3
Level of reporting of the data and metadata in food composition tables and databases (FCTs) and nutrient conversion tables (NCTs) and its implications for data documentation.

Level of Reporting	Description	Implications	Food Composition Tables and Databases/ Nutrient Conversion Tables
Food composition table (FCT level)	The source of the nutrient values (sometimes referred to as bibliography or references), and other information regarding the data compiled is reported at the highest level, i.e., reporting information on the overall food composition table. For instance, authors only provided a reference list with the sources of the nutrient values for the whole food composition table.	This level of reporting precludes the identification of the source of the mineral values as well as the geographic origin of the data	Three FCTs: Zimbabwe FCT (1989), Tanzania FCT (2008), Southern and Western Uganda (2021)
Food item (food item level)	FCTs reported one or more source/s of the nutrient value per food item entry. I.e., every food item was accompanied with at least one reference stating the source of the nutrient values.	When more than one source of information was provided per food item, we could not identify which source or sources (as nutrient values are often an average of more than one value) were used when generating the mineral concentration of each food item. Hence, only for those reporting only one source of information and under the assumption that the source provided was the original source of all the reported nutrient values, could we infer the geographic origin.	Eight FCTs/NCTs reporting at this level: Four reported more than one source per food item: Cameroon NCT, 2013, Kenya FCT, 2018, Nigeria FCT, 2019, Western Africa FCT, 2019 We inferred the geographic origin and other information for four FCTs: Lesotho FCT (2006), Zambia FCT (2009), Centre and Eastern Uganda FCT (2012), Malawi FCT (2019),
Food item-nutrient (mineral level)	Information was given for every combination of food item and nutrient reported in the FCT. For instance, one (or more) references per food entry-nutrient combination were provided.	This was the only data structure that allowed us to identify the source of the nutrient values.	Seven FCTs/ NCTs: Eastern Africa FCT, 1989, Gambia FCT, 2011, Mozambique FCT, 2011, Regional Africa NCT, 2014, Mali FCT, 2015, Western Kenya NCT, 2019, Kilimanjaro Tanzania NCT, 2019, Senegal NCT, 2019

Africa NCT, 2014 (n = 72), followed by the Western Africa FCT, 2019 (n = 59). No foods were extracted from the Southern and Western Uganda FCT, 2021 and only a small number of foods were included from the Cameroon NCT, 2013 (n = 5) and The Gambia FCT, 2011 (Prynne and Paul, 2011) (n = 11), because the food items in these tables were typically cooked and/or composite dishes.

3.3. Mineral data for sub-Saharan Africa in a subset of foods

From all the FCTs/NCTs selected for review, the mineral content of 490 food items which matched the FBS food categories, were extracted. The list of food items selected and their mineral values are reported in Supplementary Table 3. In total, there were 476 values for Fe, 458 values for Ca, 383 values for Zn, 179 values for Se and 116 values for I. No values were extracted from the Mali FCT (Koréissi-Dembélé et al., 2017; Koreissi, 2015) as nutrient values were not reported.

Iodine was the mineral reported the least often (i.e., 24% of the foods). Notably, of the five FCTs/ NCTs that reported I concentration, only the regional Africa NCT and the Senegal NCT reported no missing values, whereas the other three FCTs/NCTs reported missing values, with > 60% missing values in the food entries included in this review (Fig. 3.a). None of the FCTs/NCTs reported I concentration of any pelagic fish (Fig. 3b). Of the selected foods, Se concentration values were reported for 37%, Zn was reported for 79% and Ca and Fe were reported for > 90% of the food entries reviewed.

3.4. Documentation and source of mineral concentration values

Information (metadata) on the source of each mineral value was identified for 314 (64%) food items. There were 201 food items that provided the source of information at mineral level with one unique reference per food and mineral value, except for three food items from the Mozambique FCT, 2011 (Korkalo et al., 2011) which provided two references per mineral value. The information source was provided at the food item level for 113 food items. For the other food items (n = 176), metadata were reported at the FCT level or there were multiple references provided at food item levels, precluding our ability to trace the type and geographic origin of mineral values.

The majority of the mineral values (n = 641) reported were borrowed from African FCTs as shown in Fig. 4. The second most prevalent type of data were values from FCTs outside Africa (n = 169) for all minerals except Se, for which analytical values from secondary data (e.g., peer-reviewed publications, thesis) were more frequently reported. The most common FCT source for I and Se was the Western Africa FCT, 2010 (Stadlmayr et al., 2010) whereas for Fe, Ca and Zn, it was the Tanzania FCT, 2008 (Lukmanji et al., 2008). Of the values that were borrowed from FCTs outside of Africa, the most cited sources were the Denmark FCT (National Food Institute, 2015) for I and the USDA FCT (multiple versions) for Ca, Fe, Se and Zn (U.S. Department of Agriculture, 2017; U.S. Department of Agriculture, 2005; U.S. Department of Agriculture, 2008; U.S. Department of Agriculture, 2011).

There were 110 food item-nutrient values in six FCTs/NCTs that used analytical "secondary" values, while 106 values in three FCTs/NCTs were analytical "primary" data: Kilimanjaro Tanzania NCT (2019) (Watts et al., 2019a), Western Kenya NCT (2019) (Watts et al., 2019b) and Zambia FCT (2009) (NFNC, 2009).

3.5. Geographic origin of the mineral data for sub-Saharan Africa

The geographic origin of most of the mineral values reviewed was unknown or not traceable. For those values where the geographic origin could be identified, the most cited location for Ca, Fe and Zn was the United States (US), while for I and Se it was Denmark and Malawi, respectively.

Most of the analytical secondary data used to populate FCTs/ NCTs were collected from Malawi (14 studies) and reported the sample

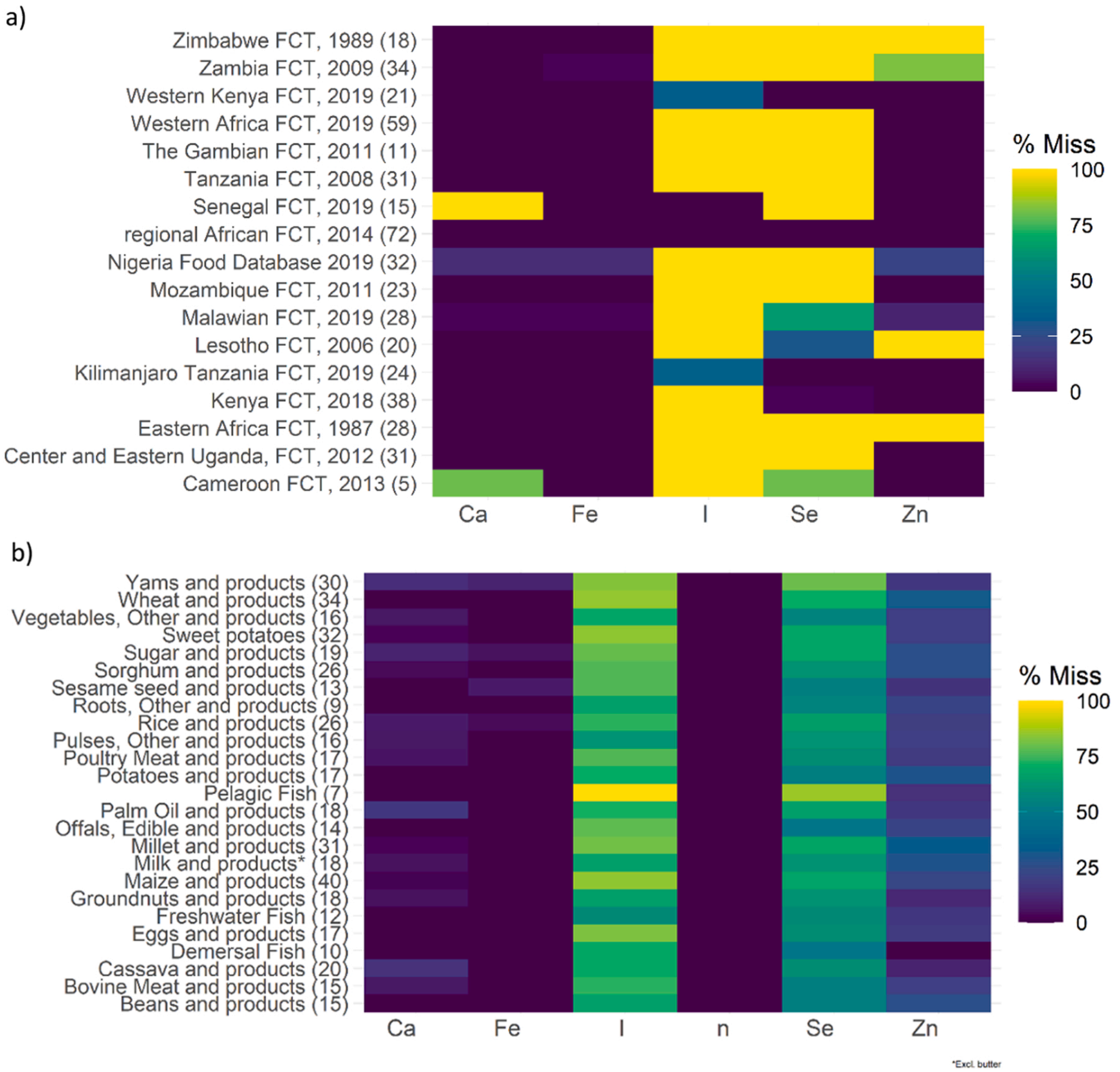

Fig. 3. Percentage of missing values per mineral of interenst in each food item. a). Percentage of missing values per mineral of interest in each FCTs reviewed. b) Percentage of missing values per mineral of interest in each food category. Number of food items per FCT/ NCT and food category are in brackets.

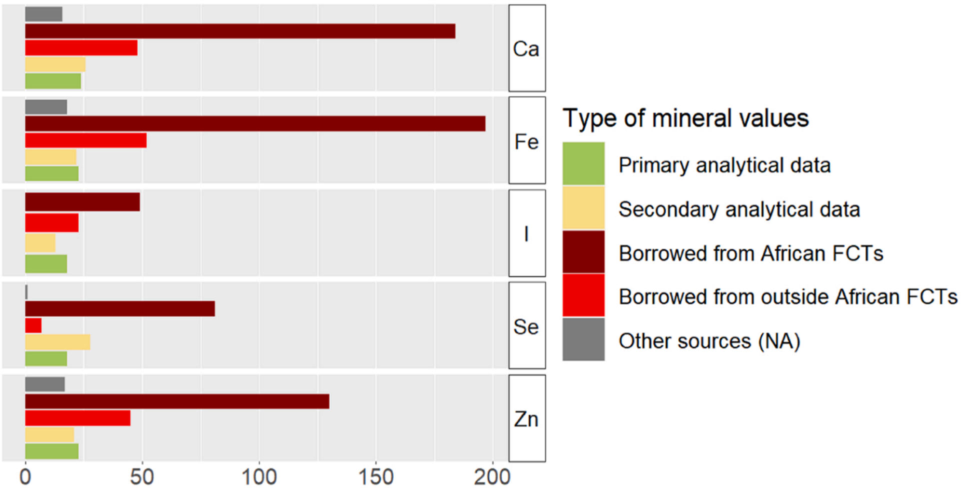

Fig. 4. Count of mineral values used to populate eleven of the Food Composition Tables and Databases/ Nutrient conversion Tables (FCTs/ NCTs) included in the review by type of value and mineral. Primary and secondary analytical values included were all from Africa.

location (only one location could not be identified because the full text was unavailable). The reporting of the sample location varied in the degree of detail, from reporting the overall location: e.g., Lilongwe, Malawi (Mumba and Jose, 2005) to providing a map with the sampling locations and associated latitude/longitude co-ordinates (Joy et al., 2015a).

Finally, the sources of only 33% (363/1084) of the mineral values were traceable to allow an identification of the geographic location of the analysed samples. As a proportion of the total number of mineral values reviewed (n = 1664), only 22% of the values from 11 of the 19 FCTs/NCTs provided sufficient information to trace the origin of food item-nutrient values.

4. Discussion

4.1. Availability of food composition tables for use in sub-Saharan Africa

Nineteen freely available FCTs/NCTs that provided Ca, Fe, I, Se and Zn food composition data, for estimating dietary intakes and supplies in sub-Saharan Africa, were reviewed. The availability of country-specific FCTs/NCTs was uneven across the region, especially for countries in the Central African region, as has been reported elsewhere (Kouebou et al., 2013). This lack of country-specific FCTs has been partially attributed to the high economic cost of compiling FCTs, the lack of funding for FCT activities, and a lack of technical and laboratory capacity for chemical analyses of micronutrients (Ene-Obong et al., 2019; Kouebou et al., 2013; Micha et al., 2018). The deficiencies of spatially-resolved food composition data and data structures have been observed previously, and the issue is not limited to sub-Saharan Africa (de Bruyn et al., 2016; Delgado et al., 2021; Ferraz de Arruda et al., 2023; Li et al., 2023; Ocké et al., 2021)). However, high-income countries generally fare better, and 75% of European countries have invested in the development of FCTs compared to only 39% of African countries, according to the food composition databases registry on the FAO/INFOODS website (INFOODS, 2020).

The importance of having country-specific FCTs have been highlighted by other authors (de Bruyn et al., 2016; Ene-Obong et al., 2019; Ocké et al., 2021). However, information on the mineral content of local foods is essential for estimating the risk of inadequate intakes of minerals to inform nutrition related policies and intervention planning to improve population health, underscoring the need for more chemical analyses of location-specific food samples in sub-Saharan African countries (Ahmad et al., 2021; Danster and Wolmarans, 2008; de Benoist et al., 2004; de Bruyn et al., 2016; Combs, J., 2015; Fuge and Johnson, 2015). Novel analyses would benefit from the improved precision and sensitivity of analytical methods and instrumentation that are currently available. Furthermore, crop mineral composition has likely changed over recent decades due to the adoption of new crop variants, and potentially due to changes in environment and management (e.g. fertilizer use) (Fan et al., 2008) and the reliance on data generated several decades ago could introduce a large amount of error to estimates of dietary mineral intakes.

4.2. Mineral data availability in selected foods

From all the food items reviewed, over 79% had values for Fe, Ca, and Zn, whereas less than 27% had values for Se and I. Lower coverage of I and Se was expected as they were included in fewer FCTs/NCTs than the other three minerals. The well-known national and sub-national geographic variability in the I and Se content of foods paired with a lack of location-specific food composition analytical values for these minerals, are common reasons for excluding I and Se from national or regional FCTs. For example, I and Se concentration values were reported in the 2010 Western African FCT but were excluded from the 2012 and 2019 editions due to these concerns (FAO et al., 2012; Stadlmayr et al., 2013; Vincent et al., 2020). Additionally, when reported, there were often missing values. For example, in the Cameroon FCT, 71% of the foods did not report Se, and in the Malawi FCT, 73% of Se and 83% of I values were missing (van Graan et al., 2019; Kouebou et al., 2013).

Since the quantities of I and Se in food items are typically 1–2 orders of magnitude lower than those of Ca, Fe, and Zn, determining their concentrations calls for more sensitive analytical approaches. This can have accessibility and cost implications, which, together with the previously mentioned geographic variability, may contribute to the high number of missing values.

A lack of relevant and accurate food composition data is problematic when attempting to characterise food system and dietary micronutrient supplies, estimate dietary micronutrient intakes, or when conducting ex-ante evaluations of nutrition interventions. For example, we were unable to identify any I concentration values for pelagic (i.e., marine) fish in the FCTs/ NCTs reviewed, although the marine environment has naturally elevated I concentrations. Fish is widely recognised as an important source of many micronutrients, particularly small fish which can be consumed whole and are often relatively affordable (Byrd et al., 2021; Hicks et al., 2019; Ryckman et al., 2021).

Equally problematic is the lack of spatially resolved mineral values, not just for Se and I, where regional differences in concentration leading to inadequate and/or excessive intakes have been extensively documented (Ahmad et al., 2021; Fuge and Johnson, 2015; Hurst et al., 2013; Ligowe et al., 2020) but also for Ca, Fe and Zn, where the spatial variability is less often characterised (Gashu et al., 2021). Thus, in some areas in sub-Saharan Africa where populations often consume locally produced foods, a single mineral value, even when sourced locally, could be inaccurate and result in misleading information for nutritional studies or programmes. However, this review found that, existing FCT data structures and compilation methods do not accommodate the integration of spatially resolved mineral composition data.

4.3. Documentation and geographic location of the mineral values

One of the aims of the scoping review was to identify the geographic location of the newly reported or borrowed mineral composition data in FCT/ NCT for use in sub-Saharan Africa by tracing it back to food samples analysed. However, the documentation sometimes did not report sufficient information to identify the source of information. In other cases, documentation was provided to identify information source which, in turn, were unavailable precluding the identification of the geographic location of the original samples used to provide mineral values. Thus, the geographic location and the relevance to the nation(s) in which the data were being used could be asserted of only 22% of the minerals in the FCTs/NCTs reviewed.

Data documentation are required to evaluate whether the nutrient values represent the nutrient content of foods in local food systems and, thus, their suitability for estimating mineral intakes of a population. Another barrier was data access in terms of where data is stored (i.e., behind paywalls, on institution hard drives, etc.) and maintained (hard copies, obsolete software formats), which again impede the use of the nutrient data for use in dietary intake estimations. Poor data documentation is one of the main barriers for evaluating data quality, reproducibility, transparency, and re-usability.

Further, some mineral values were averaged across multiple sources of food composition data, and the references were provided as a list of references either for the whole FCT, or for each food item (i.e., listing all the references for all the components together as a string). This method is recommended by some food compilation guidelines to provide representative values when sourcing nutrient concentration from single studies, and it was common practice when compiling the most recent FCTs (Western Africa FCT (2019), Nigeria FCT (2019), Kenya FCT (2018)). However, this structure (i.e., reporting average values) precludes quality assessment of individual nutrient values in the FCT, and averaged values can include data from diverse geographic locations (i.e., from India, Denmark, UK, or USA), as reported in the Western Africa or

Kenya FCTs (FAO/Government of Kenya, 2018; Vincent et al., 2020).

From the mineral values with documentation, only 33% could be traced back to the original analytical values and its geographic location. Most of the values for Ca, Fe and Zn were sourced from the US, while most of the I values were sourced from Denmark. Only for Se did the majority of values come from Africa, particularly Malawi. There is a paucity of analytical food composition data for foods grown and prepared in sub-Saharan Africa, and when available, they might not be usable because of obsolete analytical methods or insufficient documentation (Stadlmayr et al., 2013). Consequently, mineral composition data are often borrowed from other FCTs with a heavy reliance on FCTs from outside Africa (de Bruyn et al., 2016; FAO et al., 2012).

Moreover, wide variability in the mineral values of plant foods in sub-Saharan Africa has previously been reported (Barikmo et al., 2007; Stadlmayr et al., 2013). Although variation in concentrations of different minerals can be partially explained by differences in sampling and analytical methods, the variations were most likely due to crop variety and environmental factors. As highlighted by other authors, there is a need to generate local food composition data with proper data documentation (Chan et al., 2021; de Bruyn et al., 2016; Greenfield and Southgate, 2003; Lachat et al., 2016; Traka et al., 2020), and this is particularly important in countries with different agro-ecological zones, where populations consume locally sourced foods and have different traditional cooking practices, such as Nigeria (Ene-Obong et al., 2013), Cameroon (Kouebou et al., 2013), Mali (Barikmo et al., 2007, 2004), Malawi (Joy et al., 2015a), and Uganda (Scarpa et al., 2021). Hence, there is a growing recognition of the importance of spatial variability in mineral concentration in foods. For example, the US Data Central is adding two new data types (Food Foundation and Experimental Food) with a focus on nutrient variability and providing metadata that will allow users to assess the impact of that spatial variation in dietary intakes (Fukagawa et al., 2021).

4.4. Strengths and limitations

The strengths of this study included the development and publication of the study protocol and search strategy following the PRISMA-P and PRISMA-S guidelines (Moher et al., 2015; Rethlefsen et al., 2021). In addition, PRISMA-ScR guidelines (Tricco et al., 2018) were followed for reporting the results of the scoping review which were systematic including both electronic databases and other sources of information. Moreover, data and metadata were reviewed as part of the systematic approach and scripts were developed and published to increase the transparency and reproducibility of the results.

One limitation of this study was only FCTs/ NCTs that were free to access were reviewed, which may have resulted in selection bias. For example, the South Africa FCT (SAFOODS) was excluded because it is not fully open access and freely available for use and reuse, even though the SAFOODS may be of high quality (46% of values were from South African foods, and 23% were US values) and contains a high number of foods (n = 1741) (SAFOODS, 2019). However, the reason for its exclusion, i.e., it is not open access, has precluded its use previously (MoA, 2021). Similarly, 6 FCTs/NCTs were inaccessible which included FCTs that were only available as hard copies in the country's library or insufficient information (i.e., no citation or year of publication provided) prevented their identification and thus, we were unable to find them. Furthermore, those available only as hard copies that were identifiable and findable were published more than two decades ago (1957–1998). Inclusion of databases that were not freely available and accessible, would not materially change the main findings of this review in terms of data availability across the sub-Saharan Africa region, including the inadequacy of data, data structures and metadata reporting.

Another potential limitation of this study is that only raw foods were reviewed, which reduced the number of foods included from some FCTs/ NCTs. In the Southern and Western Uganda FCT all foods reported were mixed dishes, resulting in the exclusion of all data. Other FCTs/ NCTs, in which cooked foods were predominately reported, were: The Gambian FCT, the Cameroon NCT and the Centre and Eastern Uganda FCT. The inclusion of foods from the Southern and Western Uganda FCT and the Centre and Eastern Uganda FCT likely would not have changed the findings of this review, because in the former, the sources of nutrient values were only provided at the food level, and hence precluded tracing the source of the mineral values. In the latter, the primary source of data was the USDA FCT, 2008 (Hotz et al., 2012), supporting our observation that most data are either of unknown origin or not from African nations which is in line with our main results. The Gambian FCT and the Cameroon FCT reported analytical "secondary" data for some cooked food items. Additional analyses, which assessed whether the inclusion of FCTs from which few foods were reviewed would influence the results, showed the main results (i.e., most mineral values were imputed form other FCTs) did not change (Supplementary Figure 1).

Another limitation is the inclusion of specific food items which were pre-selected based on the FBS food categories. The selection of a limited number of food items was necessary to make the review feasible, and food items were chosen based on their large contributions to dietary supplies of energy and the minerals included in this review. However, FBS food categories are limited in number, which may have resulted in the omission of local foods with a high content of the minerals reviewed (Grünberger, 2014; Smith et al., 2016). Despite its limitations, FBS data have been previously used to estimate micronutrient inadequacies at global (Beal et al., 2017; Wessells et al., 2012), regional (Joy et al., 2014), and local (Watts et al., 2019) scales, because they are considered a reasonable proxy for micronutrient supply when food consumption data are not available (Coates et al., 2012).

5. Conclusion and recommendations

Food composition data are critical for dietary assessment to identify populations at risk of inadequate micronutrient intakes and inform policy and agriculture-nutrition-health intervention actions. However, this review shows the food composition data currently available for estimating dietary intakes of Ca, Fe, Zn, I, and Se, for populations in sub-Saharan Africa is limited, and rarely documents data sources at food item – nutrient level. More chemical analysis of minerals, for foods locally-grown and consumed in sub-Saharan Africa, are required, as are data structures that allow the use of spatially-relevant mineral composition data. Hence, not only should the documentation describe the analytical methods, but it should also include the geographic location of the food samples analysed. Similarly, as recommended by Greenfield and Southgate (2003), when compiling food composition from various sources, nutrient values should be annotated with sufficient information that would avoid the need of consulting the original data source. Data management and documentation could be improved by applying nutri-informatics as proposed by Chan et al., (2021). For example, the use of food and nutrition ontologies would standardise the language used in food composition allowing for the integration and interoperability of nutrition datasets (Andrés-Hernández et al., 2022). Community standards for data management should be developed to provide minimum information standards specifying essential data and documentation. All of this, together with reporting standards that would ensure comprehensive documentation would set the path to the adoption of the FAIR (Findable, Accessible, Interoperable and Reusable) principles for nutrition data (Lachat et al., 2016; Savoi et al., 2021; Top et al., 2022; Wilkinson et al., 2016).

CRediT authorship contribution statement

Lucia Segovia de la Revilla: Visualization, Project administration, Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Software, Writing - original draft, Writing - review & editing. **Elaine Ferguson:** Conceptualization, Methodology, Writing –

review & editing, Supervision. **Claire Dooley:** Conceptualization, Methodology, Writing – review & editing, Supervision. **Gareth Osman:** Data Curation, Writing – review & editing. **Louise Ander:** Writing – review & editing, Supervision, Project administration, Funding acquisition. **Edward J.M. Joy:** Conceptualization, Methodology, Writing – review & editing, Supervision, Project administration, Funding acquisition.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data Availability

Data and code are publicly available in GitHub and OSF, linked in methods section of the paper and in the published protocol (10.31219/osf.io/vd2mf).

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Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.jfca.2023.105322.

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