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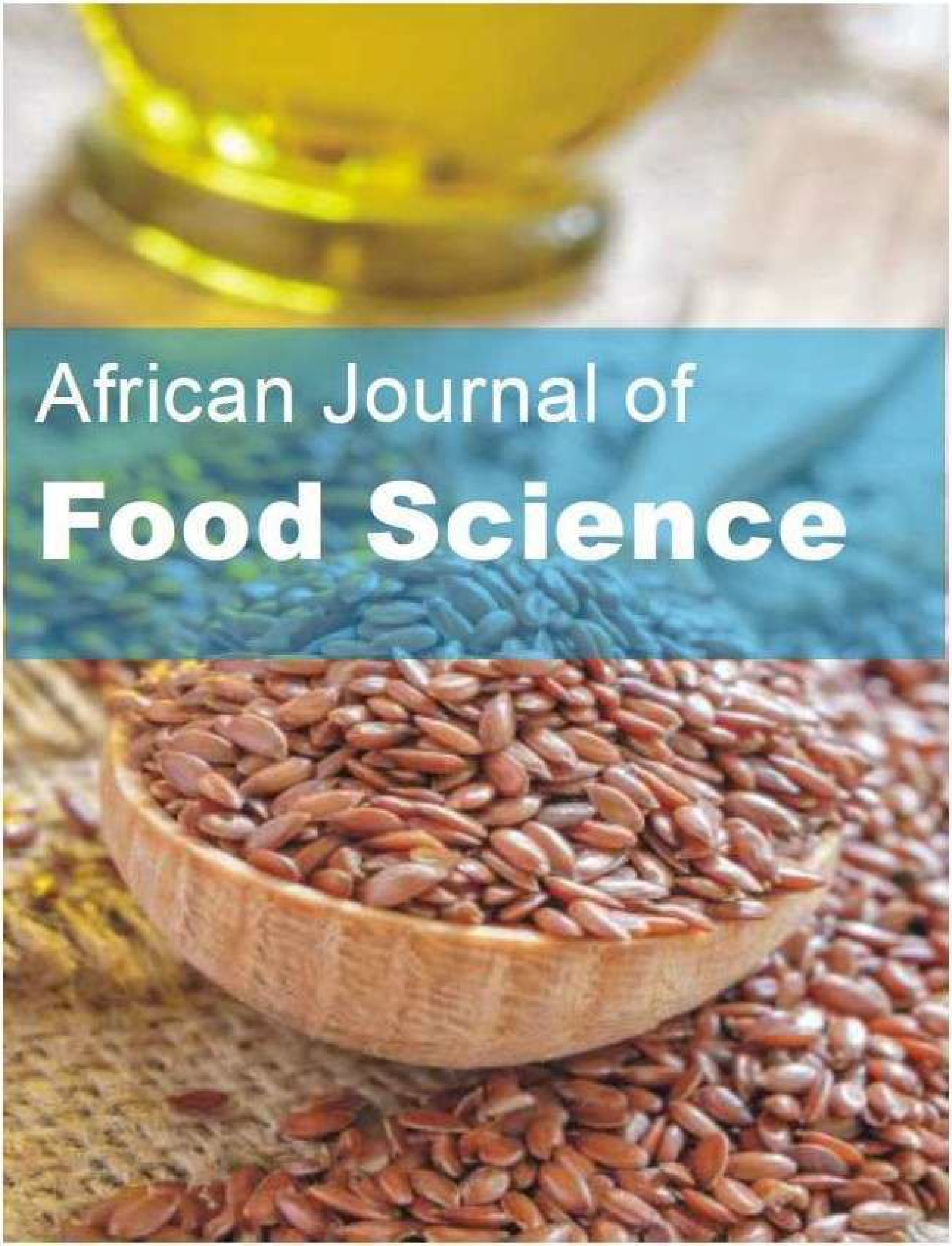

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African Journal of Food Science

Full Length Research Paper

Insights into the journey towards development of dietary guidelines: An exploration of synergy between fruit and vegetable research with food composition tables in Malawi

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Publication of the Malawi Food Composition Database (MFCDB) is a milestone towards improving the nutritional status and overall health of citizens. Following the establishment of this database, the next step involves formulating food-based dietary guidelines tailored for Malawi. However, both the database and the planned dietary guidelines are dependent on robust research on food composition. This analytical review utilizes fruit and vegetable research done in Malawi, to analyze synergies with the published food composition tables and limitations. Results point to inadequate fruit and vegetable nutrition research in Malawi. Less than 1% of published vegetable research has dealt with nutrient composition. Of this, only 15% has contributed to the food composition database, forcing 52 and 39% of entries (values) for fruits and vegetables, respectively to be borrowed. However, more research on fruit and vegetable species has been done than is captured in the database. There exists dissonance in analytical methods between research and database needs. This lack of methodology impacts overall data comparability and reliability. It is suggested that the Malawian Food Data System, provide standardized methods of analysis for various food composition parameters, priority list of species, and nutrient profiles of immediate national relevance. The planned dietary guidelines will require a multisectoral approach, and policy modifications to facilitate fit-for-purpose research in fruits and vegetables.

Key words: Dietary guidelines, food composition tables, fruits, research, vegetables, Malawi.

INTRODUCTION

Like many countries in Africa, Malawi is struggling with problems of food insecurity, hunger and malnutrition

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(Dressel et al., 2021), especially among rural children. Recognizing the importance of achieving nutrient adequacy, maintaining a healthy body; and reducing risk of chronic diseases (Murphy and Girot, 2013), the Malawi government commits to ensure provision of diverse and nutritious diets by enhancing planning and evaluation of local nutrition programs. This is enshrined in pillar number one, enabler five (Human Capital Development) of the country vision 2063. This ambition can only be achieved through understanding the nutritional composition of the food constituting the population's diets. A major step towards realization of such a vision has been the publication of the Malawian Food Composition Database (MFCDB) in 2019. The MFCDB is the first comprehensive national food composition reference document. Food composition tables that are both robust and representative of available foods are an essential tool for the development of Food Based Dietary Guidelines (FBDG) (Leclercq et al., 2001). According to van Graan et al. (2020), the next step after MFCDB is to develop Malawi food-based dietary guidelines (MFBDG). Food based dietary guidelines help to meet nutritional needs and prevent nutritional deficiencies and associated diseases (Rong et al., 2021). It is critical that any such guidelines are reflective of a nation's dietary diversity. According to da Silva Oliveira and Silva-Amparo (2018), the FAO recommends that dietary guidelines must have a national character; that is, their development should consider the situation of health and nutrition of the population of a country, providing solutions for the food and nutrition problems. Nationally representative guidelines are important for policymakers to develop and implement health interventions (Steyn et al., 2016). Differences in dietary and lifestyle characteristics nation states are evidenced for country unique dietary guidelines (Rong et al., 2021) and globally (Herforth et al., 2019). Intra-country nutrient variability due to soil, climatic, cultivar and agronomic practices; cultural variability in recipes and extraction technologies; country unique foods (Greenfield and Southgate, 2003), further necessitate country specific dietary guidelines.

The production of both the database and the planned dietary guidelines relies heavily on food nutrition research. Research is the main source of data for food composition tables. The credibility and robustness of a nation's food composition tables are thus a reflection of the nation's research output. Food nutrition research should thus ensure quality and relevance to be useful in improving and supporting the MFCDB and MFBDG and users including policy makers, food processors and health professionals (Figure 1). The envisioned FBDG for Malawi, just like elsewhere, shall heavily depend on food composition research done in Malawi. It is critical that food nutrition research is robust in terms of coverage, consistent comparability, especially in terms of methods; and relevant where it deals with foods that reflect a nation's dietary diversity.

Fruits and vegetables are called protective foods (Paul, 2018) as they are a key source of diverse nutrients mainly vitamins minerals, and several bioactive phytochemicals that promote health. Fruits and vegetables are thus key in food profiling for both nutrition tables and dietary guidelines. In Malawi, research in fruit and vegetable has been ongoing even prior to MFCDB. The advent of the food composition database, as a standard, has unique requirements in terms of expected nutrient profiles and their methodology of determination and manner of presentation. It is thus imperative to evaluate the existing research, in terms of its fulfillment of expectations from MFCDB and the subsequent guidelines. Such an analysis should guide future food nutrition research so that it produces reliable data that is fit for purpose. With a focus on fruits and vegetables, this paper seeks to interrogate how existing research outputs, for example, published papers, reports and academic thesis, sync with MFCDB in terms of relevance, compliance, coverage and consistency, and its potential as a key data source for the envisioned dietary guidelines for Malawi.

Specifically, this study sought to firstly, relate existing research and its input into MFCDB; secondly, assess methodology (uniformity, and equipment) for nutrient assessment; thirdly assess nutrient profiles measured (completeness) and finally determine the species/crop coverage. It is hoped that the analysis of the relationship will aid in informing research, facilitating its relevance and of expected quality, leading to a reliably adequate MFCDB. This effort requires a multi-sectoral approach, the key to which are researchers and research institutions, government commitment, nongovernmental players and community members at large.

METHODOLOGY

Data for this work made use of secondary sources. These included the Malawi food composition database (MFCDB) document and published works on fruit and vegetable nutrient composition in Malawi. Three search engines were used: Google Scholar, Mendeley and Agris-FAO. First, general search terms were used such as "phytochemical composition vegetables Malawi; phytochemical AND composition AND fruits AND Malawi;" The word phytochemical was later substituted by, "chemical", "nutritional" and "proximate". A more directed search included the most studied species after (Mazibuko et al., 2023). Such search terms included the exact species name and a given nutritional component of interest for example, 'minerals AND cabbage', 'Mango AND vitamins', 'carbohydrate AND in AND Peas'. Scientific names were also used alongside common names. All publications with results from original (not reviews) nutritional analysis were included as further data sources. Data obtained from each article were: Nutritional components measured (and their values); plant species name/s; sample preparation procedure; methods and equipment used in analysis; units of measurement for various parameters; and year (and type) of publication. Nutritional components were mostly, but not exclusively, those presented in MFCDB. Additional data on acceptable methods and units of measurements were sourced from recently published literature, including key references such as the 'Official Methods of Analysis of the Association of Official Analytical Chemists' (Horwitz and Latimer, 2005), the 'Food and Agricultural Organization (FAO)-sponsored' publication by Greenfield and Southgate (2003), and FAO Food and

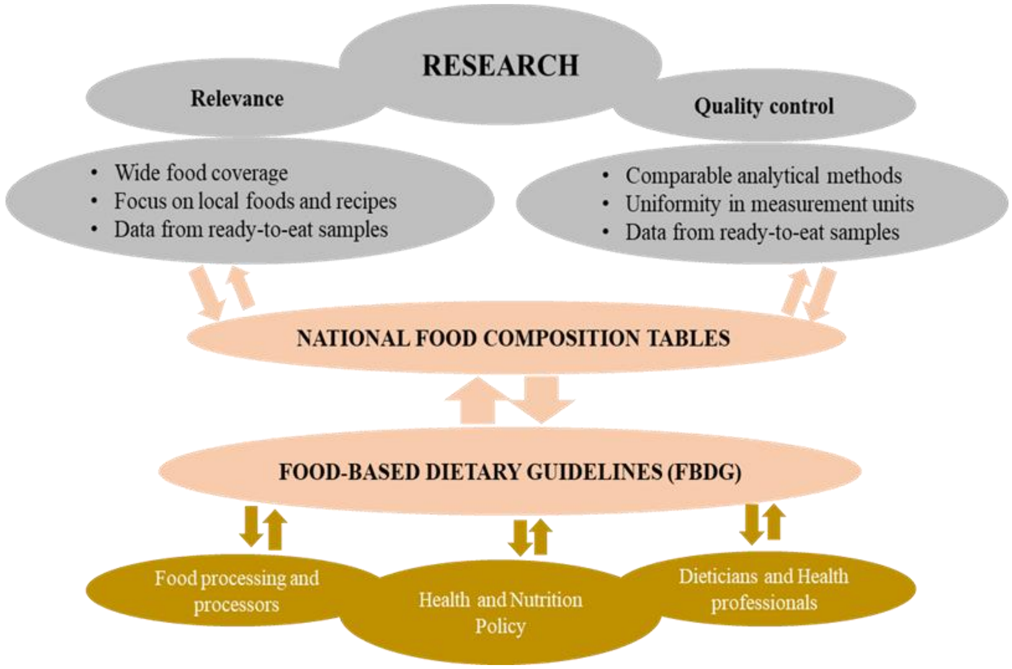

Figure 1. Schematic representation of research role in food composition databases and food-based guidelines. Robust research determines the outcomes and impacts end users.

Nutrition Paper 77 by Maclean et al. (2003).

RESULTS AND DISCUSSION

Malawian research input into food composition database

The sources of fruit and vegetable data for the Malawi food composition database (MFCDB) comprised thesis, peer-reviewed publications and other official reports. This study identified twenty-two publications that evaluated fruit and vegetable nutrient profiles. Figure 2A shows that most data, used in the MFCDB has been obtained from the thesis compared to published articles. The Malawi food composition database used just three published articles (on fruits and vegetables) representing 15% of available research data. It is clear, local fruit and vegetable research was not substantively included into the MFCDB. In terms of parameters measured (Figure 2B), more parameters are captured in the database than are available in the existing published research. The least evaluated are vitamins as compared with minerals and proximate composition. Regarding the number of species evaluated (Figure 2C); research has dealt with a relatively higher number of species than are included in the food composition database.

The relatively minor contribution to local fruit and vegetable research to the database could partly be due to two reasons; first, because of 'strict screening' (van Graan et al., 2020) that was done during the database compilation process, and second, most research was conducted before publication of the database (prior to 2019), presenting a possibility that researchers lacked clarity on approaches that would qualify their work for contribution to the database. The MFCDB however, does not provide a screening criterion, inhibiting clarity for underutilization of available research data. The database used a relatively large number of theses, five (three undergraduate and two postgraduate). While thesis data is useful, journal and other published data are more robust since they are exposed to the peer review process. The findings are indicative of a disjoint between research and expectations of the MFCDB.

Methodological approaches in fruit and vegetable research in Malawi

In determining food composition, it is key to use validated methodologies to ensure result comparability and quality (Nielsen, 2017). Results for food composition have been found to differ depending on the method of analysis and the type and age of instrument used (Krätschmer and Schächtele, 2019). Newer methods of analysis are generally more accurate and tend to provide higher composition values (Westenbrink et al., 2013) with older methods of analysis dogged with underestimations (Longvah et al., 2017) for most parameters. In pursuit of methodological uniformity (Baur and Ensminger, 1977), the commonly used in food composition evaluations methods are those by the Association of Official Analytical

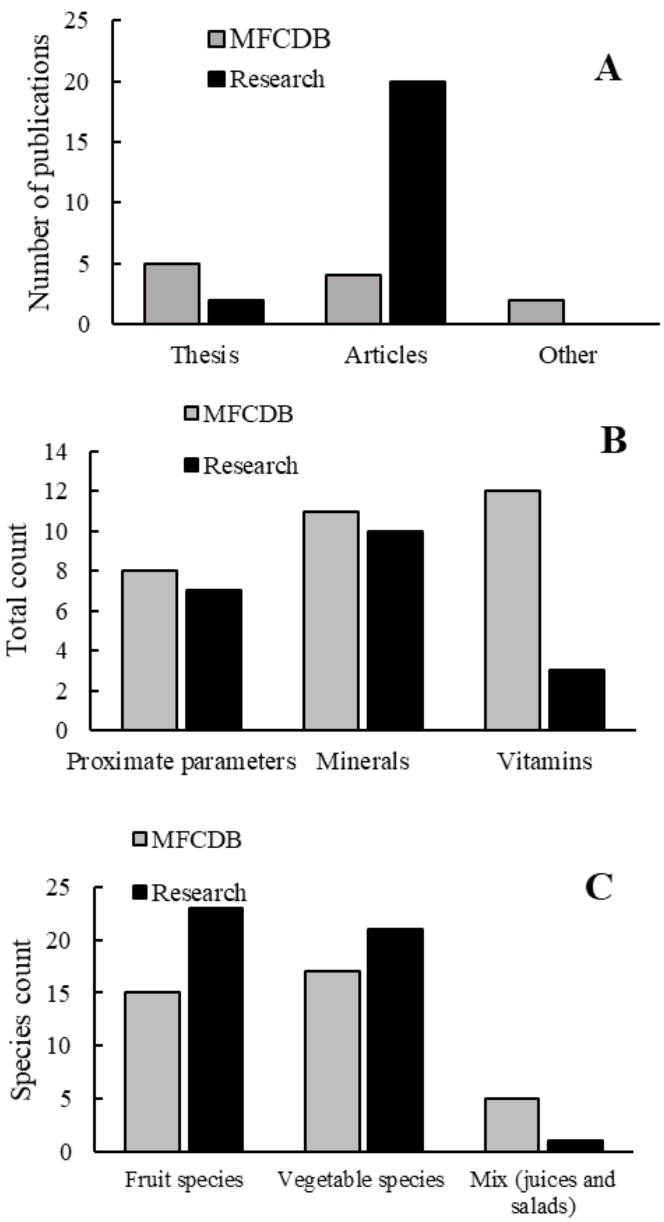

Figure 2. A comparison between research and the Malawi food composition database. A- compares data sources; B- evaluated nutrient profiles; C- number of species evaluated.

Chemists (AOAC).

Methodology reference

The Malawi food composition database does not specify recommended methods for analysis. For example, the database lists three different methods for analyzing crude fiber, three methods for fats, and four for minerals such as calcium (van Graan et al., 2020). An analysis of the published fruit and vegetable research in Malawi show that various methods are used for the analysis of various food profiles. Of the traced authors, eighteen (79%) referred to the AOAC methods of analysis. Of these, 66% indicated the exact official method while 34% just made general reference to AOAC, without specifying the method number or name. The naming specific method or number enables informed result comparison and replication experiments. For example, while the AOAC website lists fifteen differently numbered methods for crude fat determination, these are applicable to different substrates and a general reference to AOAC becomes seriously inadequate. The Malawi food composition database has dealt with this by naming the actual method/approach in addition to referring to the AOAC publication, for example, "Chloroform methanol extraction (AOAC, 1990)" for fatty acid analysis. An alternative approach is substituting the name with the exact method number, for example, AOAC 940.28-1940. Other methodological issues of concern include a lack of methodology authority by some authors, citation of 'incorrect' methods, and a lack of reference to any methodology by a few authors. Figure 3 provides a synopsis of issues identified from published research on fruits and vegetables in Malawi.

Sample preparation

Sample preparation is a key step any analytical process as it affects analytical performance (Md Noh et al., 2020). For food nutrition composition, sample preparation is a key determinant of whether obtained values are reflective of a food as consumed. Debate exists on whether samples for nutritional analysis should be raw or "as consumed". It has been argued that even when the same methods are used, values would significantly differ when one analysis used raw food and another used food 'as consumed' (Slimani et al., 2000). Food preparation process, principally cooking, is known to change food product nutritional quality and phytochemical contents (Bengtsson et al., 2008; Margier et al., 2018). Sikora and Bodziarczyk (2012) documented losses of up to 69 and 56% of vitamin C and polyphenols, respectively and positive accumulation of copper and manganese due to cooking. Other researchers have further analyzed food composition not only as eaten but at physiological temperature conditions (Saura-Calixto et al., 2000). It is generally accepted that limitations to food composition tables include their inability to accurately predict labile nutrients, and differences between values from raw versus cooked food (Greenfield and Southgate, 2003). Charrondiere et al. (2012) recommends the use of yield factors (YF) and retention factors (RF) to convert raw sample values to recipes (as eaten state). However, these conversions have shortfalls in that they differ across countries, and they need to be country specific (Lisciani et al., 2022) to reflect as much as possible, the food habits of the population.

The Malawi food composition database presents fruits and vegetable items, mostly in "as eaten" state. Such as approach avoids the challenge of conversion of intake data,

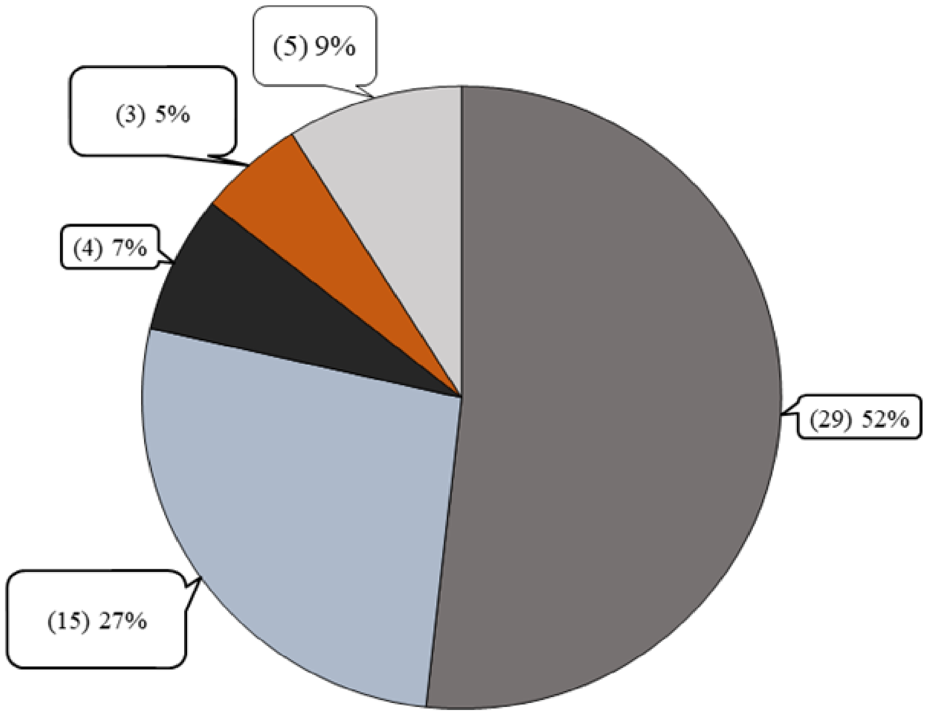

Figure 3. A methodological comparison between fruit and vegetable publications and the Malawi food composition database. A total of 56 methods were utilized to generate different data. Most methods (29 (52%)) referred to the official AOAC methods. Of the total, 4 (7%) did not provide any authority behind methods; 5 (9%) used other common methods by Osborne and Voogt (1978) and those by the International Organization for Standardization (ISO); and 3 (5%) referred to AOAC methods used for meat substrates (misplaced).

for complex food items, into servings for individual food groups (Holmes et al., 2018). An analysis of the reviewed articles however shows only 17% studies analysed (at least indicated) food as consumed. We opine that food composition assessment ought to be done of ready to eat samples, that is, where the sample is in "as eaten" form whenever possible. This is important and would enable accurate provision of dietary guidance from the FBDGs that are planned for development. Recipe diversity across Malawian societies, and the impact on food composition, could mean the same food can potentially provide variable nutrients to consumers. Apart from making FBDGs more accurate and relevant, food composition tables developed from ready-to-eat materials would thus subtly reflect a nation's diet.

Units of measurement

Units of measurement were largely presented in the MFCDB format except for minerals where most authors used mg kg^{-1}, or µg g^{-1}, parts per million (ppm) and not mg (g)100g^{-1} of edible portion (sample). These can be easily converted to the database-required format. The methodological shortfalls alluded to above can have impact on research data and its reliability for Malawi. According to Silva et al. (2021), some major limitation of food composition tables (databases) is unstandardized analytical methods to determine nutrients composition of foods; unstandardized presentation of food composition values; presentation of one single mean value for each food component (rarely accompanied by the number of samples considered and error estimation) and limited coverage of food items, nutrients and other components. Methodological standardization for Malawi needs to be done. The Malawian Food Data System (MAFOODS) must provide guidance in this regard to help researchers conform to the expectation of the food composition database. This will ensure robust and fit-for-purpose Malawi food-based dietary guidelines as planned.

Assess nutrient profiles measured (completeness)

Overall, of the proximate parameters, ash, crude fat, proteins, moisture and fibers are the most evaluated in fruits and vegetables. Calcium, phosphorus, magnesium and zinc are the most studied mineral elements. When compared, proximate parameters have been evaluated more in fruits than in vegetables except for ash and

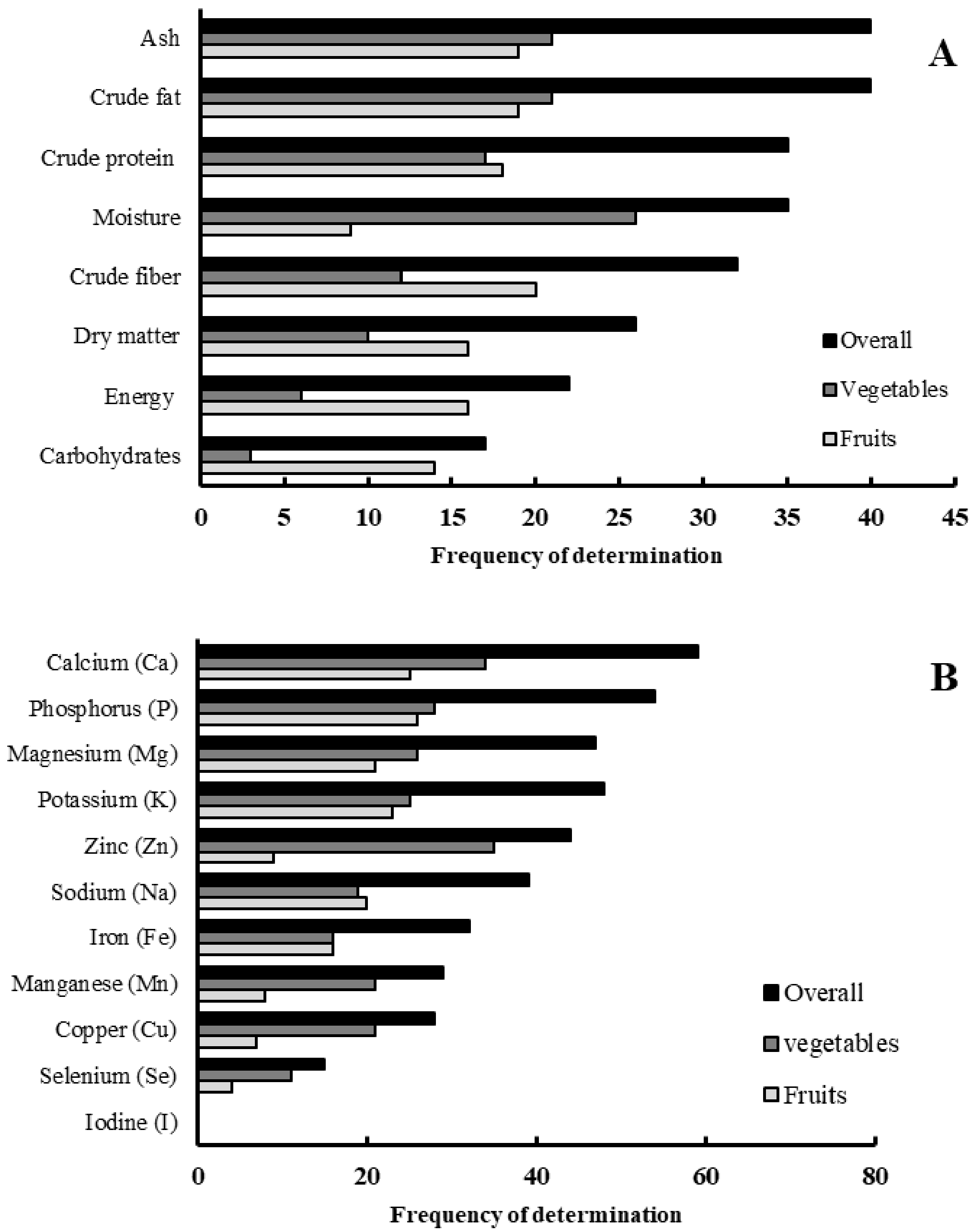

Figure 4. The generalized extent of nutritional evaluations done categorized for proximate factors (**A**) and mineral (**B**) for fruits and vegetables.

moisture (Figure 4A), while mineral elements have been studied more in vegetables than in fruits (Figure 4B). The least studied profiles are energy and carbohydrates in vegetables and moisture in fruits. Regarding mineral composition, microelements (Zn, Mn, Cu, Se and I) in both fruits and vegetables are adequately studied (Figure 4B). It is crucial that food nutrient assessment research should provide a complete nutrient profile for each food if such data will meaningfully contribute to diet need tabulations (Schakel et al., 1997).

Species/crop coverage

According to Leclercq et al. (2001), a food composition database that is both comprehensive and representative of available foods, is an essential tool for developing Food Based Dietary Guidelines. In Malawi, fruits and vegetables are key foods in most people's diets, and an assessment their coverage is vital. The diversity of fruits and vegetables consumed is equally high. It is imperative to understand the nutritional contribution of fruits and vegetables to community health. Food composition tables ought to be as exhaustive as possible in terms of coverage of consumed plant species in a community (Greenfield and Southgate, 2003). It has been found that just 23 fruit species and 22 vegetable species have had their nutrient composition evaluated, a relatively small fraction compared to the vegetable diversity in Malawi yet not very different from a review by Mazibuko et al. (2023) who recorded thirty-four vegetable species, most of which were introduced species. In terms of vegetable research output, nutritional composition research constitutes less than 1% (23 papers) of approximately all publications (506) on vegetable research in Malawi, as documented in Mazibuko et al. (2023). Regarding fruits, little, in terms of research is published regarding nutrient composition. The inadequate research in fruits and vegetables is reflected in the MFCDB where 39% (443 database entries) and 52% (420 database entries) of vegetable and fruit entries are borrowed from other databases.

Borrowing, even when properly done, is found to be generally inaccurate and lowers quality of a database (Gjorshoska et al., 2022). The most evaluated vegetable species (>80% of combined proximate and mineral composition), are Maungu (*Cucurbita maxima*); Nyemba (*Phaseolus vulgaris*), Mbatata (*Ipomoea batatas*), Bonongwe (*Amaranthus* sp.), Chinangwa (*Manihot esculenta*) and Chisoso (*Biden Pilosa*). The most evaluated fruit species are Malambe (*Adansonia digitata*) and Maula (*Parinari curatelifolia*). Generally, in Malawi research into fruits remain non-substantive. In this paper just 17% (4 papers) of publications evaluated fruit, with a strong bias towards indigenous species (Saka et al., 1994, 2008).

The fruit list in the food composition database comprises some most readily available ones while the research focus is on seasonal indigenous fruits. Indigenous fruits vary in their geographical distribution and thus not cosmopolitan in Malawi. The lack of reliable fruits specific statistics has been attributed to little technical and financial support (Kachule and Franzel, 2013). For indigenous fruits, it is safe to assume that consumption coincides with seasonal availability. Tables 1 and 2 provide a species-specific nutrient evaluation status. These tables provide a key reference for directing research attention, especially regarding undetermined nutrients in specific fruits and vegetables.

Outstanding issues for research

Research in fruits and vegetable's nutrient composition is currently inadequate to fully support the national food composition database. Of the forty-two nutrient parameters outlined in the database, twenty-three have not been evaluated, representing just 41% research coverage. For evaluated parameters, no single species has a full profile (Table 2). The existing shortfall calls for urgent research that could be used to update the existing database. Some authors evaluated parameters that are not directly related to what the MFCDB constitutes such as phenolics, carotenoids, tannins, amylose and amylopectin. With the production of the database, such analytical effort needs to be directed to other relevant food nutrients (Figure 5).

Of special concern is the vitamin analysis. Of all the food composition parameters, vitamins are the least determined in Malawi among fruits and vegetables. There is only one publication that evaluated vitamin A in fruits (Saka et al., 2008) and six that evaluated vitamin C. This notwithstanding, vitamins are a key food group with a role in the normal functioning of the immune and nervous system (Onyambu et al., 2021), and preventing a host of diseases and other health challenges including the current COVID-19 (TurrubIATes-HernánDez et al., 2021). Fruits and vegetables are known as key sources of vitamins A, C, E, K (Akram et al., 2020), vitamin D_3 and provitamin D_3 (Jäpelt and Jakobsen, 2013) and vitamin B complex (Ali et al., 2022). Most vegetables found in Malawi have elsewhere been found to contain particularly higher amounts of vitamins A, C and carotenoids (Aworh, 2018). Such vegetables include *Cleome gynandra, Cucurbita maxima, Ipomoea batatas* (leaves), *Vigna unguiculata, Manihot esculenta* (cassava leaves) (Aworh, 2018), and form a key component of most Malawians. Their inclusion in the envisioned FBDG would enhance the relevance of such guidelines.

A call to fruit and vegetable vitamin data

Vitamins comprise an important food group and in Malawi deficiency has noted impacts. Fruits and vegetables are a key source of vitamins and minerals including vitamins K, E, C and B-complex (Zhang et al., 2018). Currently, Malawi's efforts to deal with vitamin deficiency have focused on biofortification. Biofortification efforts have focused just on vitamin A (Babu et al., 2016). Vitamin-fortified foods include cooking oil, sugar and wheat flour. Biofortification has so far focused on sweet potatoes and beans. While fruits and vegetables are known source of vitamins and minerals, the vitamin content of most fruits and vegetables remain unknown as revealed in this review. Reasons for underrepresenting vitamin data in Malawian research are not easy to isolate. Generally, the determination of vitamins in food requires extra care. First, determination procedures are time-consuming and labor intensive and require extreme attention to detail and costly. Secondly, the determination of vitamins lies in the analytical method and equipment, leading to large interlaboratory variability (Jakobsen et al., 2019).

In the case of Vitamin D, Holden and Lemar (2008) reported the difficulty in measuring amounts of specific forms of vitamin D, concluding that existing methods lack specificity, sensitivity and precision and require updating

Table 1. Nutrient profiling and coverage for fruit species as found in published literature.

Local/Englich name (Botanical name)	Dry matter (Ca)	Crude protein (Fe)	Ash (Mg)	Crude fat (P)	Crude fiber (K)	CHO (Na)	Energy (Zn)	Moisture (Cu)	Mn	I	Se	Total count proximate (mineral)	% Coverage
Baobab (*Adansonia digitata*)	1-(1)	1-(1)	1-(1)	1-(1)	1-(1)	1-(1)	1-(1)	1-(1)	(1)	(0)	(0)	8-(9)	100-(82)
Akee (*Blighia sapida*)	0-(1)	1-(0)	1-(0)	1-(1)	1-(1)	0-(0)	1-(0)	1-(0)	(0)	(0)	(0)	6-(3)	75-(27)
Avocado (*Persea americana*)	0-(1)	0-(0)	0-(1)	0-(1)	0-(1)	0-(1)	0-(1)	1-(1)	(1)	(0)	(0)	1-(8)	13-(73)
Matowo (*Azanza garckeana*)	1-(1)	1-(1)	1-(1)	1-(1)	1-(1)	1-(1)	1-(0)	0-(0)	(0)	(0)	(0)	7-(6)	88-(55)
Banana (M*usa* sp.)	0-(1)	0-(0)	0-(0)	0-(1)	0-(0)	0-(0)	0-(1)	1-(0)	(1)	(0)	(1)	1-(5)	13-(46)
Chitimbe (*Bauhinia thornningii*)	1-(1)	1-(0)	1-(1)	1-(1)	1-(1)	1-(1)	1-(0)	0-(0)	(0)	(0)	(0)	7-(5)	88-(46)
Nthudza (*Flacourtia indica*)	1-(1)	1-(1)	1-(1)	1-(1)	1-(1)	1-(1)	1-(0)	0-(0)	(0)	(0)	(0)	7-(6)	88-(55)
Guava (*Psidium guajava*)	0-(1)	0-(0)	0-(1)	0-(1)	0-(1)	0-(1)	0-(1)	1-(1)	(1)	(0)	(1)	1-(9)	13-(82)
Indian plum (*Flacourtia indica*)	0-(1)	0-(0)	0-(1)	0-(1)	0-(1)	0-(1)	0-(1)	1-(1)	(1)	(0)	(1)	1-(9)	13-(82)
Jackfruit (*Artocarpus heterophyllus*)	0-(1)	1-(0)	1-(0)	1-(1)	1-(1)	0-(0)	1-(0)	1-(0)	(0)	(0)	(0)	6-(3)	75-(27)
Mango (*Mangifera indica*)	0-(1)	0-(1)	0-(0)	0-(1)	0-(0)	0-(0)	0-(1)	1-(1)	(1)	(0)	(1)	1-(7)	13-(64)
Maula (*Parinari curatelifolia*)	1-(1)	1-(1)	1-(1)	1-(1)	1-(1)	1-(1)	1-(1)	0-(1)	(1)	(0)	(0)	7-(9)	88-(82)
Mufula (*Sclerocarya birrea*)	1-(1)	0-(1)	1-(1)	1-(1)	1-(1)	0-(1)	0-(1)	0-(0)	(0)	(0)	(0)	4-(7)	50-(64)
Mazaye (*Strychnos cocculoides*)	1-(1)	1-(1)	1-(1)	1-(1)	1-(1)	1-(1)	1-(0)	0-(0)	(0)	(0)	(0)	7-(6)	88-(55)
Mazaye (*Strychnos innocua*)	1-(1)	1-(1)	1-(1)	1-(1)	1-(1)	1-(1)	1-(1)	0-(0)	(0)	(0)	(0)	7-(6)	88-(55)
Syyzygium guineense	1-(1)	1-(1)	1-(1)	1-(1)	1-(1)	1-(1)	1-(0)	0-(0)	(0)	(0)	(0)	7-(6)	88-(55)
Bwemba (*Tamarindus indica*)	1-(1)	1-(1)	1-(1)	1-(1)	1-(1)	1-(1)	1-(0)	0-(0)	(0)	(0)	(0)	7-(6)	88-(55)
Msikitsi (*Trichilia emetica*)	1-(0)	1-(1)	1-(1)	1-(1)	1-(1)	1-(1)	1-(0)	0-(0)	(0)	(0)	(0)	7-(5)	88-(46)
Masuku (*Uapaca kirkiana*)	1-(1)	1-(1)	1-(1)	1-(1)	1-(1)	1-(1)	1-(0)	0-(0)	(0)	(0)	(0)	7-(6)	88-(55)
Matembela (*Vangueria infausta*)	1-(1)	1-(1)	1-(1)	1-(1)	1-(1)	1-(1)	1-(0)	0-(0)	(0)	(0)	(0)	7-(6)	88-(55)
Mpindimbi (*Vitex doniana*)	1-(1)	1-(1)	1-(1)	1-(1)	1-(1)	1-(1)	1-(0)	0-(0)	(0)	(0)	(0)	7-(6)	88-(55)
Mpindimbi (*Vitex mombassae*)	0-(1)	1-(0)	0-(1)	1-(1)	1-(1)	0-(1)	0-(0)	0-(0)	(0)	(0)	(0)	3-(5)	38-(46)
Masawo (*Ziziphus mauritiana*)	1-(1)	1-(0)	1-(1)	1-(1)	1-(1)	1-(1)	1-(0)	0-(0)	(0)	(0)	(0)	7-(5)	88-(46)

(1) is evaluated parameter and (0) is not evaluated. Numbers in brackets represent mineral data those without brackets represent proximate composition data. The proximate parameters presented here are the same with those in the Malawi food composition database

and modification. Further, the procedure requires experienced technicians, and the quality of the results is directly proportional to the experience of the analyst. There is a lack of standard reference materials with certified values (Byrdwell et al., 2008) validated for a few materials. The results show that vitamins presented the highest variability, particularly vitamin C and differences were more prominent for vegetables than for fruits (Beltramo et al., 2023).

Currently, analytical procedures have improved (Md Noh et al., 2020) and research in Malawi can benefit from newer equipment and available standards to drive the vitamin research for fruits and vegetables. The involvement of fruits and vegetables (readily available foods) with known vitamin composition in diets would go a long way in dietary planning and policy formulation.

Table 2. Nutrient profiling and coverage for vegetable species as found in published literature.

Common name (Botanical name)	Dry matter (Ca)	Crude protein (Fe)	Ash (Mg)	Crude fat (P)	Crude fiber (K)	CHO (Na)	Energy (Zn)	Moisture (Cu)	Mn	I	Se	Total count proximate (mineral)	% Coverage
Bonongwe (*Amaranthus* sp)	1-(1)	1-(1)	1-(1)	1-(1)	1-(1)	0-(1)	0-(1)	1-(1)	(1)	(0)	(1)	6-(10)	75-(91)
Bell paper (*Capsicum annum* L.)	1-(0)	0-(0)	0-(0)	0-(0)	0-(0)	0-(0)	0-(0)	0-(0)	(0)	(0)	(0)	1-(0)	13-(0)
Bengal beans (*Cicer arietinum*)	0-(1)	0-(0)	0-(1)	0-(1)	0-(1)	0-(1)	0-(1)	1-(1)	(1)	(0)	(1)	1-(9)	13-(82)
Chisoso (*Biden Pilosa*)	1-(1)	1-(1)	1-(1)	1-(1)	1-(1)	1-(0)	1-(1)	1-(1)	(0)	(0)	(0)	8-(7)	100-(64)
Cassava (*Manihot esculenta*)	0-(1)	1-(1)	1-(1)	1-(1)	1-(1)	0-(1)	1-(1)	1-(1)	(1)	(0)	(1)	6-(10)	75-(91)
Chinese cabbage (*Brassica* sp)	0-(1)	0-(0)	0-(1)	0-(1)	0-(1)	0-(1)	0-(1)	1-(1)	(1)	(0)	(0)	1-(8)	13-(73)
Luni (*Cleome gynandra*)	0-(1)	1-(1)	1-(0)	0-(0)	1-(0)	0-(0)	0-(1)	1-(0)	(0)	(0)	(0)	4-(3)	50-(27)
Cocoa yam (*Colocasia esculenta*)	0-(1)	1-(1)	1-(1)	1-(1)	1-(1)	0-(1)	1-(1)	1-(0)	(1)	(0)	(0)	6-(8)	75-(73)
Cowpeas (*Vigna unguiculata*)	0-(1)	1-(1)	0-(1)	1-(1)	1-(1)	1-(1)	1-(1)	1-(1)	(1)	(0)	(0)	6-(9)	75-(82)
Maungu (*Cucurbita maxima* L.)	1-(1)	1-(1)	1-(1)	1-(1)	1-(1)	1-(1)	0-(1)	1-(1)	(1)	(0)	(1)	7-(10)	88-(91)
Mwamunaligone (*Galinsoga parviflora*)	1-(0)	1-(0)	1-(0)	0-(0)	1-(0)	0-(0)	0-(0)	0-(0)	(0)	(0)	(0)	4-(0)	50-(0)
Garlic (Bulb) (*Allium sativum*)	1-(0)	1-(0)	1-(0)	0-(0)	1-(0)	0-(0)	0-(0)	0-(0)	(0)	(0)	(0)	4-(0)	50-(0)
Ginger (Rhizome) (*Zingiber officinale*)	1-(0)	0-(0)	0-(0)	0-(0)	0-(0)	0-(0)	0-(0)	0-(0)	(0)	(0)	(0)	1-(0)	13-(0)
Jute mallow (*Corchorus olitorius*)	0-(1)	0-(1)	1-(1)	1-(0)	0-(0)	0-(0)	0-(1)	0-(1)	(0)	(0)	(0)	2-(5)	25-(46)
Nyemba (*Phaseolus vulgaris*)	0-(1)	1-(1)	1-(1)	1-(1)	1-(1)	1-(1)	1-(1)	1-(1)	(1)	(0)	(1)	7-(10)	88-(91)
Lima beans (*Phaseolus lunatus*)	0-(1)	0-(0)	0-(1)	0-(1)	0-(1)	0-(1)	0-(1)	1-(1)	(1)	(0)	(1)	1-(9)	13-(82)
Moringa (*Moringa oleifera*)	0-(1)	0-(1)	1-(1)	1-(0)	0-(0)	0-(0)	0-(1)	0-(1)	(0)	(0)	(0)	2-(5)	25-(46)
Okra (*Abelmoschus esculentus*)	0-(1)	0-(0)	0-(1)	0-(1)	0-(1)	0-(1)	0-(1)	1-(1)	(1)	(0)	(1)	1-(9)	13-(82)
Pigeion pea (dried) (*Cajanus cajan*)	0-(1)	0-(0)	0-(0)	0-(1)	0-(0)	0-(0)	0-(1)	1-(1)	(1)	(0)	(1)	1-(6)	13-(55)
Red Onion (*Allium cepa*)	1-(0)	0-(0)	0-(0)	0-(0)	0-(0)	0-(0)	0-(0)	0-(0)	(0)	(0)	(0)	1-(0)	13-(0)
Chikande (*Satyrium buchananii*)	1-(0)	1-(1)	1-(0)	1-(1)	1-(0)	0-(0)	0-(0)	0-(0)	(0)	(0)	(0)	5-(2)	63-(18)
Sweet potato (*Ipomoea batatas*)	1-(1)	1-(1)	1-(1)	1-(1)	1-(1)	0-(1)	1-(1)	1-(1)	(1)	(0)	(1)	7-(10)	88-(91)

(1) is evaluated parameter and (0) is not evaluated. Numbers in brackets represent mineral data those without brackets represent proximate composition data. The proximate parameters presented here are the same with those in the Malawi food composition database.

Conclusion

The development of food-based dietary guidelines (FBDGs) for Malawi is directly related to the robustness of the FCDB. Key issues that need attention include ensuring that the database is representative of Malawians' dietary diversity, standardization of methodology of analysis, enhancement of food composition research and capacity building.

1. Capturing Malawi's dietary diversity: Capturing, compilation and analysis of cross-cultural vegetable recipes in Malawi is one way of ensuring the development of relevant dietary guidelines. The existing Malawi food composition database has "borrowed" some data for some vegetables irrespective of the stringent criteria for borrowing as highlighted by (Greenfield and Southgate, 2003).
It is generally impossible to acquire nutrient composition of all foods in a society due to intra-

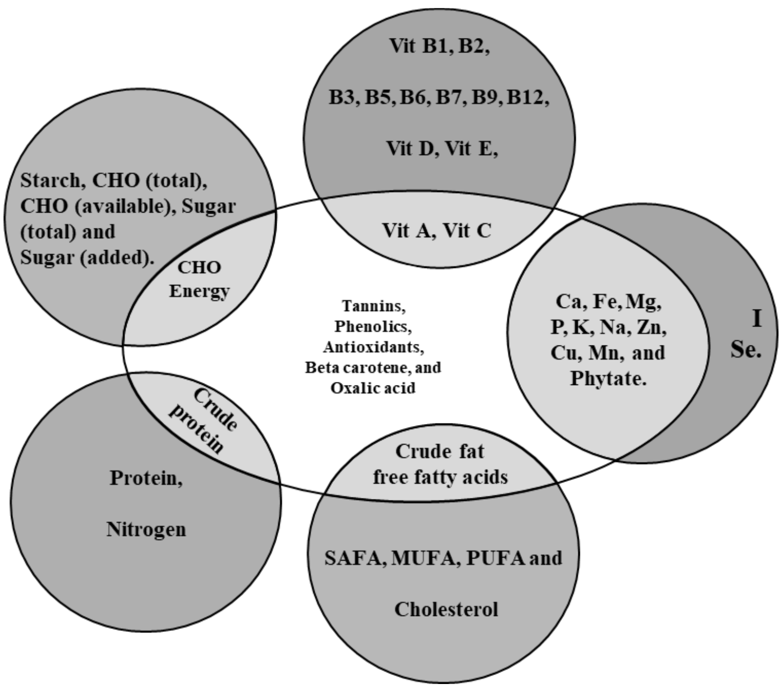

Figure 5. A schematic representation of various food profiles (circles) and what has been evaluated (oval/egg-shaped) and other determined parameters that are not clearly represented in the database.

country nutrient variability emanating from factors such as soil, climate, cultivar and agronomic practices; variability in recipes and extraction technologies; country unique foods (Greenfield and Southgate, 2003).

2. Standardization of research: Standardization of methods of analysis is needed to ensure credibility and comparability of data. Standardization should not only be on methods but on instrumentation and in units of expression and for use (where possible).

3. Enhancing food composition research: Malawi fruit and vegetable food composition research is grossly inadequate. The need exists to deliberately promote this kind of research. As indicated earlier, complete food nutrient profiling is a near-impossible task in part due to costs. Based on Haytowitz et al. (2002) costing for one full nutrient profile in the United States, in Malawi about $5,000 is the cost for a complete food profile (with Malawi's database of forty parameters). Prioritization of foods and nutrients that are of national health concern is one pragmatic approach for Malawi to ensure relevance of envisioned food-based dietary guidelines for Malawi.

4. Capacity building: Capacity building of both humans and infrastructure is another fundamental need as has been highlighted by Schönfeldt and Hall (2013) to ensure quality food composition data. The establishment of sustainable research networks among research institutions is equally critical to enhance collaboration and reduce duplication of effort. Regarding infrastructural capacity, there is a need for a dedicated food nutrient composition laboratory as done elsewhere (Haytowitz et al.,1996). Such laboratories must focus on the provision of robust data that is representative of national dietary diversity. They also should serve as research quality control in food and nutrition analyses.

The improvement of the database and development of the food-based dietary guidelines is a national multisector and multiplayer endeavor. Such an effort shall require policy modifications, investment and wider institutional collaboration. There is an urgent need for dissemination and orientation by MAFOODS of expectations from various stakeholders.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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Effect of 300Gy Gamma (ɣ) radiation dose on Nigerian onion: A proximate composition

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Onion (*Allium cepa*) samples purchased from one of the most populous markets (Bodija market) in the south-western part of Nigeria were irradiated with a 300Gy dose of ɣphotons using ɣBEAMX200, while some of these onions were also kept as control (non-irradiated). Proximate analyses were carried out on both irradiated and non-irradiated onion. The proximate composition revealed 0.16, 11.63 and 7.90% reduction in moisture, crude protein and ash, respectively in the irradiated sample. Additionally, the irradiation led to the increase of crude fiber, carbohydrates and crude fat contents by 3.36, 11.51 and 57.14%, respectively in the irradiated sample over the non-irradiated. Conclusively, the irradiation of onion with 300Gy does not significantly change the moisture content, but positively changed the fiber content and carbohydrate contents of the irradiated onions.

Key words: Onion (*Allium cepa*), carbohydrate, Gamma photons, proximate composition, irradiation.

INTRODUCTION

Food irradiation is a process of exposing food to a controlled amount of ionizing radiation such as ɣ rays to destroy harmful organisms and increase their shelf-life (Farkas, 2006). The use of ionizing radiation to destroy harmful biological organisms in farm produce is considered safe with well- proven process that is widely accepted (Sharma et al., 2020).

Depending on the absorbed dose of radiation, various effects could be observed resulting in reducing storage losses, extended shelf life and/or improved microbiological and parasitological safety of foods (Farkas and Mohácsi, 2011; Yuan, 2018).

Post-harvest food losses pose serious problems in most countries in Africa especially sub-Saharan Africa because of low level of development in food preservation (Gathambiri, 2021). In some cases, as much as 3% of cereal and 20.60% of tubers, root crops and bulbs are lost (Kaminski and Christiaensen, 2014; Sheahan and Barrett, 2017).

Onion in Nigeria are predominantly grown in the northern part of Nigeria and are consumed almost daily in all households in the country because of their importance in adding flavor to food and have many health benefits as well (Blamadottir, 2019).

Onion provided flavor, colour and texture to a wide variety of dishes. But much more than the flavor, the health benefits of onion make it highly significant in human health (Blamadottir, 2019). While onions are not

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particularly high in most nutrients, they contained anti-inflammatory, anti-cholesterol, anti-cancer and antioxidant components such as quercetin (Sheneni et al., 2018). Quercetin is known for its antibacterial and antioxidant activities (Ramos et al., 2006).

Fisetin, a flavonoid found in onion has a great role in treating chronic diseases (Pearlman et al., 2016). Onions are rich in vitamin C and chromiun, a trace mineral tied to insulin response (Sheneni et al., 2018).

Fat-soluble vitamins are particularly destroyed by irradiation and tocopherol is more sensitive to pasteurization doses, 0.2-0.25 kGy (Diehl, 1992). Regarding vitamin C, no alterations were registered in onions receiving irradiation doses enough for sprouting inhibition (Kilcast, 1994). Elevated irradiation dosages (0.03-0.15kGy) led to complete inhibition of sprouting and mitosis of onion, independent of application moment while low doses (0.002-0.01kGy) did not give in any desirable effects on food (Pellegrini et al., 2000).

Due to the significant loss recorded in the storage of onion in Nigeria, irradiation of onion can be used to increase their shelf-life for a longer period (Sharma et al., 2020) and according to Agbaji et al. (1981), ɣ irradiation was proven to increase the shell-life of Nigerian onion. After a thorough study of the literature, no study has reported the proximate composition of Nigerian onion irradiated up to 300 Gy; thus, the focus of this study was to know the effect of irradiation on the proximate composition of the available Nigerian onion in the market which are being consumed by the public, especially in south-western Nigeria

This study was carried out to investigate the effect of 300Gy ɣ irradiation on the proximate composition of Nigerian onion.

MATERIALS AND METHODS

Raw onion (*Allium cepa*) was collected at Bodija market (the main market in south-western Nigeria) for the experimental study. Some were irradiated to 300Gy of ɣ photons with ɣ BEAMX200 which is available at the National Institute of Radiation Protection and Research, while some were set aside (non-irradiated) as control.

For the irradiation, the air kerma dose rate of ɣBEAMX200 Co-60 ɣ photons irradiator at source-to-sample distance of 80cm for a radiation field size of 10 x 10cm^2 was determined with an IBA ion chamber connected to IBA electrometer (IAEA TRS 398). The time to irradiate the onion with 300Gy of ɣ photons was determined using the concept of dose equal product of dose rate and irradiation time. Each sample was hung on a retort stand at 80cm of 10 x 10 cm^2 field size along the central axis of the radiation beam, and irradiated with 300Gy of ɣ radiation.

Proximate analysis

Both the irradiated and non-irradiated were then analyzed for their proximate values at the Department of Human Nutrition of the University of Ibadan, Ibadan, Oyo State Nigeria.

Proximate composition was determined on the two sets of onions (irradiated and non-irradiated) which included: moisture content, crude protein, crude fat, crude fiber, ash content, and total carbohydrate. The procedure followed was in line with the official method of analysis stated in AOAC (1990).

Moisture content

The dried clean porcelain dish was weighed empty. Five grams of *Allium cepa* (irradiated and non-irradiated) was put in the dish separately and weighed. It was oven-dried at 70-80^{o}C for 20 h until weight is constant. The sample was cooled in a desiccators, dry weight of the sample and dish were taken. The moisture content of the sample was calculated as indicated in equation 1.

$$\%\ \text{Moisture} = \frac{\text{Wet weight} - \text{dry weight}}{\text{wet weight}} \text{x } 100 \quad (1)$$

Crude protein

Into a 1000 ml standard flask containing about 600 ml of distilled water, 8.9 ml of 35% hydrochloric acid was put and made up to the mark. This gave approximately 0.1N HCl standardized by titration and then diluted 10 times. % crude protein was determined from equations 2, 3 and 4. The percentage protein (wet or dry basis) is as follows:

$$\%\ \text{Protein} = \%\ \text{nitrogen x } 6.25 \quad (2)$$

Where 6.25 is the protein-nitrogen conversion factor for all protein by-products.

The percentage nitrogen (wet weight basis) as follows:

$$\%\ \text{Nitrogen (wet)} = \frac{(\text{A}-\text{B})\ \text{X}\ 1.4007}{\text{Weight of sample}} \text{ x } 100 \quad (3)$$

Where: A = vol. (mL) std. HCl x normality of std. HCl, B = vol. (mL) std. NaOH x normality of std. NaOH

The nitrogen content on dry basis (when moisture content is known) as follows:

$$\%\ Nitrogen\ (dry) = \frac{\%\ Nitrogen\ (wet)}{(100 - \%\ moisture)} \text{x } 100 \quad (4)$$

General factor = 6.25

Allium cepa = N_{acid} x 5. 55

Where N_{acid} = normality of acid =0.01N

Crude fat

A clean boiling flask (250cm^3) was dried in oven at 105-110^{0}C for 30 min, transferred into a desiccator and allowed to cool. The cooled boiling flask was filled with 200cm^3 petroleum ether. Two grams of the sample was accurately weighed into labeled thimbles. The extraction thimble was lightly plugged with cotton wool and the thimble was removed with care. Petroleum ether was collected at 105^{0}C for 1 h. It was then transferred from the oven into desiccators, allowed to cool and weighed. The % crude fat was calculated using equation 5.

$$\%\ Fat = \frac{Weight\ of\ fat}{Weight\ of\ sample} \text{x } 100 \quad (5)$$

Crude fiber

One gram of *Allium cepa* (irradiated and non-irradiated) was

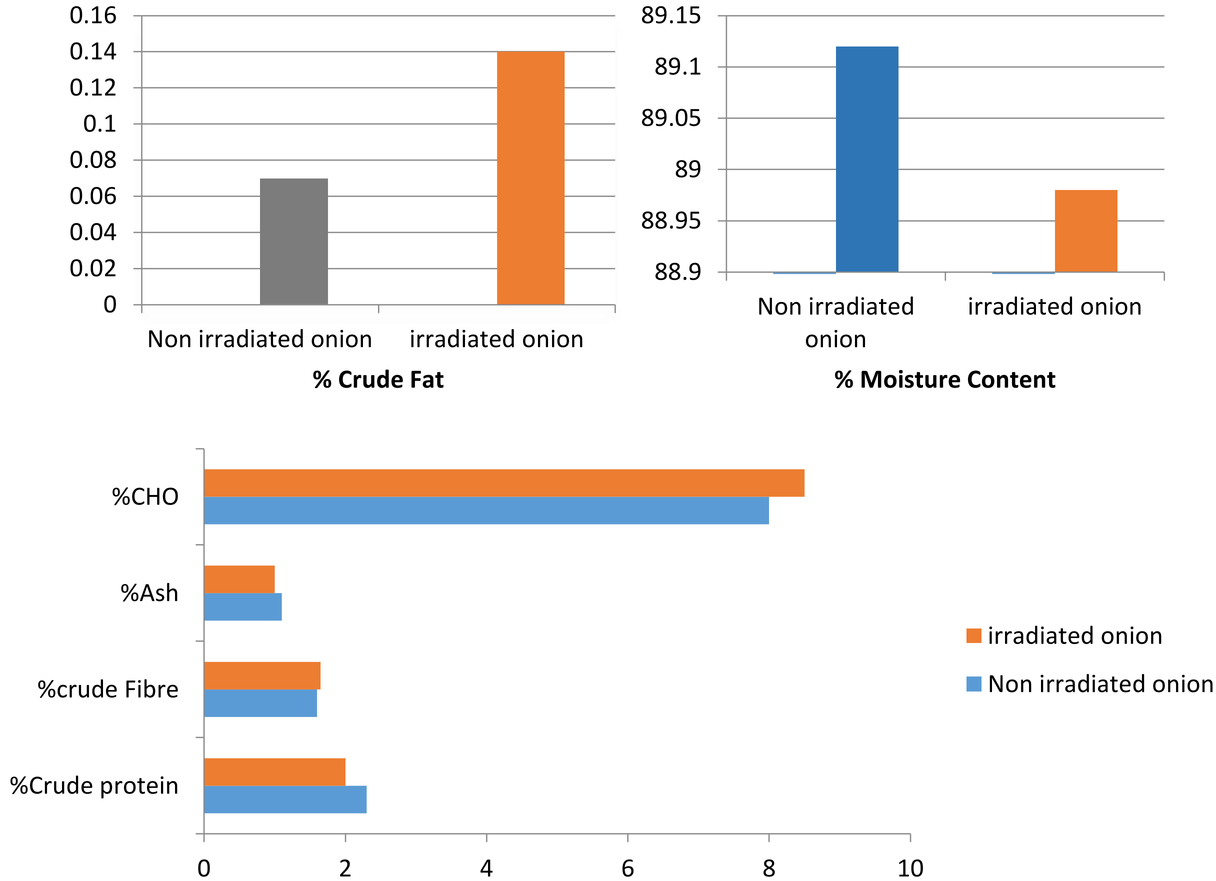

Figure 1. Proximate composition of Nigerian onion irradiated with 300Gy Ɣ radiation and the non-irradiated.
Source: Authors

weighed into 500ml conical flask. Hundred ml of trichloroacetic acid digestion reagent which is a mixture of 500ml glacial acetic acid, 450 ml water and 50 ml conc. nitric acid was added.

The mixture was boiled and refluxed for 40 min. Liquid loss was prevented with a water jacketed condenser. The flask was removed from the heater, cooled under cold tap and filtered. The residue was dried at 600°C overnight in muffle furnace, cooled in a desiccator and weighed. The % crude fiber was determined by using equation 6.

$$\% \text{ Fiber} = \frac{\text{Difference in weight}}{\text{Weight of sample}} \times 100 \quad (6)$$

Ash

Two-5g finely ground, dry sample (irradiated and non-irradiated) was separately weighted into a silica/porcelain crucible (avoid dust contamination after weighing). The sample was charred on an electric heater to drive off most of the smoke. Then the sample was transferred into a preheated muffle furnace at 600^0C and heated at this temperature for 2 h.

Crucible was cooled in a desiccator and grey ash obtained was weighed. Its % was determined using equation 7.

$$\% \text{ Ash} = \frac{\text{Ash weight (g)}}{\text{Sample weight (g)}} \times 100 \quad (7)$$

Carbohydrate

Carbohydrate content was determined using equation 8, by subtracting the % of moisture, ash, proteins, fiber and fats from 100.

$$\%\text{Carbohydrate} = 100 - (\%\text{moisture} + \%\text{crude protein} + \%\text{crude fat} + \%\text{crude fiber} + \%\text{Ash}) \quad (8)$$

Statistical analysis

Independent sample T-test was carried out on the proximate composition of the two sets of onions (irradiated and non-irradiated) to show if the nutritional content of irradiated onions is significantly different from the control (non-irradiated) ones.

RESULTS AND DISCUSSION

Figure 1 showed that the proximate composition of Nigerian onion irradiated with 300Gy Ɣ radiation and the non-irradiated. From Figure 1 and Table 1, it could be observed that the moisture, ash and crude protein contents of the irradiated sample became lower by 0.16,

Table 1. Proximate composition of Nigerian onion irradiated with 300Gy ɣ radiation and non-irradiated onion with their % differences.

Treatment	% Moisture content	% Crude protein	% Crude fat	% Crude fiber	% Ash	% CHO
Control (non- irradiated						
1st	89.13	2.14	0.07	1.19	0.76	7.47
2nd	89.08	2.17	0.07	1.20	0.75	7.45
3rd	89.15	2.14	0.06	1.19	0.76	7.49
Mean*	89.12±0.04	2.15±0.02	0.07±0.01	1.19±0.01	0.76±0.01	7.47±0.02
Irradiated						
1st	89.08	1.90	0.11	1.22	0.69	8.26
2nd	88.93	1.91	0.11	1.23	0.70	8.35
3rd	88.92	1.90	0.11	1.24	0.70	8.37
Mean	88.96±0.07	1.90±0.01	0.11±0.00	1.23±0.01	0.70±0.01	8.33±0.06
%Difference	0.16	11.63	57.14	3.36	7.90	11.51

No of replicates= 3.
Source: Authors

Table 2. Statistical analysis of the proximate composition of irradiated and non-irradiated onions.

Proximate composition	*P-value
Moisture content	0.0620
Crude protein	0.0000
Crude fat	0.0002
Crude fiber	0.0053
Ash content	0.0002
CHO	0.0000

*P value > 0.05 means no significant difference and P value < 0.05 means there is significant difference.
Source: Authors

7.9 and 11.63%, respectively than the non-irradiated sample. The reduction in the moisture content could have been caused by a possible raise in the temperature of the irradiated sample (Bliznyuk et al., 2022). The reduction in the protein content of the irradiated onion is also in agreement with the Agbaji et al. (1981) and this could be due to the deamination of polypeptides and protein in the irradiated onion by the ɣ radiation.

Furthermore, the crude fiber, carbohydrate and crude fat contents of the irradiated sample were increased by 3.36, 11.51 and 57.14% over the control. It is interesting to observe that the crude fat that increased after irradiation is also in agreement with Agbaji (1988), who investigated that the lipid content of Nigerian onion after irradiation although the radiation doses are different.

The statistical analysis in Table 2 showed that, there is no significant difference between the moisture content of irradiated onions and the non-irradiated ones (p>0.05), but there is significant difference (p< 0.05) between the crude protein, crude fat, crude fiber, ash and CHO contents of irradiated and non-irradiated onions. This implied that the crude protein, crude fat, crude fiber, ash and CHO contents of the irradiated onions are significantly different from the non-irradiated onions. Comparing Tables 1 and 2, the proximate composition showed that positive significance in crude fiber and carbohydrate contents while negative significance in crude protein, crude fat and ash content. This is in agreement with the Munir et al. (2017) who investigated the effect of gamma radiation on the shelf life, physiological and nutritive value of onion. The positive significance is as a result of % increase in crude fiber and CHO contents. The presence of crude fiber in diet aids digestion and improves the elimination of waste from human systems, while CHO will be a good source of glucose (Khan et al., 2013; Munir et al., 2017).

Conclusion

It could be observed that exposure of onion to ɣ ray up to 300Gy do not significantly change the moisture content. The protein, fat, Ash, fiber and CHO contents of the irradiated onions is significantly different from the control (non-irradiated) onions. Both the fiber and the CHO content were positive significant because of their relevance in human diet.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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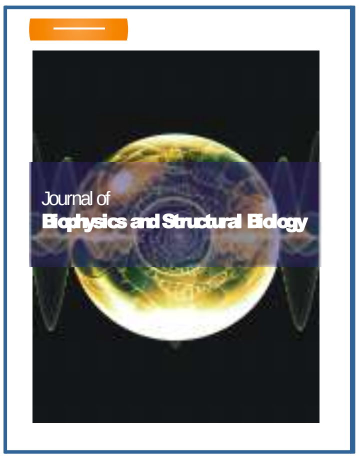

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