



Nutrition and Health (including climate and ecological aspects)

Indigenous vegetables: a sustainable approach to improve micronutrient adequacy in Tanzanian women of childbearing age

Maria Vittoria Conti¹ · Rachele De Giuseppe¹ · Maria Cristina Monti² · Angela G. Mkindi³ · Naelijwa H. Mshanga³ · Silvia Ceppi⁴ · John Msuya⁵ · Hellas Cena^{1,6}

Received: 17 March 2020 / Revised: 8 January 2021 / Accepted: 13 January 2021 / Published online: 2 February 2021
© The Author(s), under exclusive licence to Springer Nature Limited 2021

Abstract

Background/objectives Increasing dietary diversity is a viable strategy for addressing micronutrient malnutrition in women of childbearing age (WCA) from low-income countries. Recently, it has been demonstrated that some indigenous vegetables (IV) with high nutrient density may help to ameliorate micronutrient's intake. The Minimum Dietary Diversity index for Women (MDD-W) could be considered as a proxy to describe one important dimension of women's diet quality. This cross-sectional study aimed at exploring aspects contributing to micronutrients adequacy in Tanzanian WCA, with a focus on IV consumption and other socio-demographic factors.

Subjects/methods Data collection was conducted among urban and peri-urban women in Arusha city, Tanzania. Socio-demographic factors were collected using a structured interview. Information on IV consumption and MDD-W calculation were obtained using a 24-h recall.

Results One-hundred and forty-one women aged 14–49 years were interviewed. Sixteen per cent of the sample consumed at least one portion of IV/day. The total median MDD-W was 4.0 (IQR. 3.0–5.0) and it was adequate in the 44% of the sample. Women who consumed IV had MDD-W 0.66 points (95% CI: 0.02–1.30, $p = 0.046$) higher than those who did not; consuming IV had an odds ratio of more than three times concerning women not consuming IV (OR: 3.30, 95% CI: 1.24–8.81, $p = 0.017$).

Conclusions The IV consumption is positively associated with micronutrient adequacy and its absence from the diet can be an indicator of micronutrient deficiencies in vulnerable people such as WCA. For that reason, this study suggests that IV consumption may improve micronutrient deficiency in WCA.

These authors contributed equally: Maria Vittoria Conti, Rachele De Giuseppe

✉ Maria Vittoria Conti
mariavittoria.conti01@universitadipavia.it

¹ Dietetics and Clinical Nutrition Laboratory, Department of Public Health, Experimental and Forensic Medicine, University of Pavia, Pavia, Italy

² Section of Biostatistics and Clinical Epidemiology, Department of Public Health, Experimental and Forensic Medicine, University of Pavia, Pavia, Italy

³ The Nelson Mandela African Institution of Science and Technology, Arusha, Tanzania

⁴ Cooperation and Development, Istituto Oikos, Milano, Italy

⁵ Department of Food Technology, Nutrition and Consumer Sciences, Sokoine University of Agriculture, Morogoro, Tanzania

⁶ Clinical Nutrition and Dietetics Service, Unit of Internal Medicine and Endocrinology, ICS Maugeri IRCCS, Pavia, Italy

Introduction

In developing countries, such as sub-Saharan Africa, women play a pivotal role in the food system since they feed the world, not only as agricultural food producers but also as household members with knowledge and physical ability to process, preserve and prepare food [1].

The central role that women play in the food system has an impact on the health of their children, considering the direct relationship between nutrition and health [1]. Women impact their children's nutrition both indirectly through their nutritional status during pregnancy [2], and directly through childcare [1].

However, women in developing countries, who are primarily responsible for feeding their families, are more vulnerable to dietary deficiencies of macro and micro-nutrients with the consequent risk of not meeting the recommended nutrient intake, mainly for micronutrients

[1, 2]. The importance of vitamin and mineral adequate intake is critical for women of childbearing age (WCA) and during pregnancy in supporting healthy foetal development [2]. Indeed, inadequate micronutrients intake in women before and/or during pregnancy affects foetal programming and offspring outcomes, causing irreversible damage to neurocognitive and physical functioning in newborns [2]. This intergenerational malnourishment cycle [3], which could be related to a scarce dietary diversity, a qualitative measure of food consumption that reflects the access to a variety of foods [4]. Diets without diversity remain a widespread challenge both in most countries including the developing ones, despite the abundance of food produced by modern intensive agricultural systems [5]. In sub-Saharan Africa, an already investigated sustainable way [1] to partially counteracted dietary diversity is increasing the consumption of indigenous vegetables (IV) [1]. IV are rich in nutrients and can provide a valid nutrient source with a higher nutritional profile than the most common vegetables available in the market. However, many of these IV have been neglected for several socio-economic or political reasons [6, 7].

As reported by Chitambo et al. [8] in some African countries, there is a renewed interest in IV farming and consumption because of their role in food and nutrition security. In a recent narrative review [1], the authors discussed the nutritional properties of IV from Sub-Saharan Africa (also named neglected underutilized species), including the potential role of local agriculture strategies in improving food production, dietary diversity and in expanding income-generating activities for women [8].

Several indices have been developed to estimate dietary diversity [9]. Particularly, the Minimum Dietary Diversity for Women (MDD-W) index is a viable tool for addressing an important dimension of women's diet quality, such as micronutrient adequacy in WCA [9].

Therefore, considering scientific evidence mentioned above [7, 9], the present cross-sectional study aimed at exploring aspects contributing to micronutrient adequacy in Tanzanian WCA living in the urban and peri-urban area of Arusha region, with a focus on IV consumption and other socio-demographic factors.

Materials, subjects and methods

Study setting

This cross-sectional study was conducted in Tanzania that is divided into 31 administrative regions [10], 21 in Tanzania mainland and 5 in the Archipelago of Zanzibar. Regions are divided into administrative district councils, which are in turn divided into wards [11]. The study area is located in

Arusha region where Arusha town (third major urban Centre of the country) is the regional capital.

The recruitment was conducted both in urban areas (Arusha town) and in peri-urban ones (defined as areas that are in some form of transition from strictly rural to urban), in places where volunteers could gather. Specifically, women living in urban area were gathered in Ngarenaro, Olorieni and Elerai wards; while women living in the peri-urban area were gathered in the Sokoni 1, Baraa and Kimandolu wards.

Sampling

The recruitment occurred between June 2019 and August 2019, data were collected throughout a Swahili language live interview, by two local trained enumerators of Istituto OIKOS East Africa, a Tanzanian NGO placed in Arusha town that promotes the protection of biodiversity and sustainable use of natural resources as tools to fight poverty.

With their active contribution, and with community-based participatory research and communication, Oikos asked the women who were in contact with the association if they intended to participate in the project. WCA (14–49 years of age) were eligible if they had not been diagnosed with any disease and recorded as living in the urban or peri-urban area of Arusha region. Thus, all eligible women were invited to participate in the meeting organized in the different wards; only 20 participants per day were interviewed in each ward. Finally, 141 female volunteers were interviewed. All the participants were asked to sign an informed consent.

Data collection

The interview consisted of two sections aiming at collecting different information about:

- (i) Demographic, social, educational and economic variables;
- (ii) IV consumption and micronutrient adequacy by evaluating dietary intake and eating habits.

In the first section of the interview, demographic and social data included marital status, disability or having a disabled person in charge in their household. If one or more of these conditions were present, women were considered 'vulnerable', and the variable was dichotomized (yes/not). Religious identity was also investigated (e.g. Muslim, Catholic or Lutheran). Data regarding educational level were categorized into three different classes: low level (no school education), medium level (primary or secondary school), high level (high school—level A or technical certificate or diploma or graduation) [12]. The economic data collected are referred to as the money spent weekly for

grocery, expressed in shillings (Tanzanian shillings, TZS). Finally, participants were asked if they have been given any dietary advice or treatment by a health professional.

The second section of the interview was conducted using a 24-h recall (24-hR) [13, 14], that is the most frequent instrument used for population assessment in low-income countries, as already reported by others [14]. Indeed, the method can be designed to be culturally sensitive and cognitively easy, making it especially suitable for respondents with limited education [14].

In the present research, the 24-hR allowed the investigation of IV consumption and the estimation of micronutrient adequacy through the calculation of MDD-W index [9].

Thanks to the presence of highly trained interviewers, dietary recalls did not require respondents to be literate, aside from the memory, and provided detailed information on food preparation, brand names and portion sizes [13]. Briefly, women were invited for a structured interview intended to capture detailed information on foods and beverages consumed in the past 24 h, helping recall using a coloured food photography atlas with household measures related to national portion sizes [13, 14]. In the case of complex recipes, specific questions were asked about each ingredient and method of cooking.

Authors identified sub-Saharan IVs, referring to a list previously reported [1]; IV consumption was eventually estimated by using the 24-hR.

To investigate the possible micronutrients' deficiency, the MDD-W index [9] was calculated. According to the MDD-W protocol [9], foods recorded by the 24-hR were classified into ten groups: (1) grains, white roots and tubers, and plantains; (2) pulses; (3) nuts and seeds; (4) dairy; (5) meat, poultry and fish; (6) eggs; (7) dark green leafy vegetables; (8) other vitamin-A-rich fruits and vegetables; (9) other vegetables; (10) other fruits. Food groups included in MDD-W index mostly suggested diet quality with adequate micronutrient intake considering 11 important micronutrients: vitamin A, thiamine, riboflavin, niacin, vitamin B₆, folate, vitamin B₁₂, vitamin C, calcium, iron and zinc [9]. For each food group, a dichotomous variable was used: "1" for women who consumed any food item in the group at least one time per day and '0' for those who didn't consume any food within that food group. The MDD-W index was calculated by summing up the number of food groups consumed. The adequacy in micronutrients intake was reached when the index was equal to or higher than 5 [9].

Statistical analysis

Based on scientific evidence [15, 16] and data collected, the testable hypothesis was developed with the expectation that demographic, economic, educational factors and consumption of IV would be associated with a higher MDD-W.

Sample size: the Wilcoxon signed-rank test (motivated by uncertainty concerning the assumption of normality) was used to determine whether the MDD-W population mean μ equals a specified value μ_0 (FAO). Therefore, we wanted to test the null hypothesis that the population MDD-W mean is $\mu = \mu_0 = 4$ ([12], FAO) against the alternative hypothesis that at least $\mu = \mu_0 \pm 0.5$. The standard deviation in the population was estimated to be $s = 1.5$. The results indicated that we need at least $N = 102$ subjects to ensure a power > 0.90 . We decided to increase the sample size by 30% (133 subjects), considering the possible dropout.

Data were reported as absolute numbers and percentages for categorical variables. Numerical variables were described using the median and inter-quartile range. Differences related to quantitative variables between two groups of women were evaluated by the Mann–Whitney U test or unpaired Student t -test as appropriate, while differences related to quantitative variables among more than two groups were evaluated by the Kruskal–Wallis test or the Analysis of Variance. Chi-square or Fisher exact tests were applied to explore categorical variables differential distribution among groups of women. Association of MDD-W index with other characteristics of the sample were tested using simple and multiple linear regression models. The regression coefficient value represents the mean change in the MDD-W index given a one-unit change or a category change in the predictor (a positive sign indicates that as the predictor variable increases, the MDD-W index also increases; while a negative sign indicates that as the predictor variable increases, the MDD-W index decreases). Unconditional logistic regression analysis was applied to assess the adjusted association of adequate micronutrients intake (MDD-W index ≥ 5) with relevant predictors obtained from the linear regression analysis framework. Adjusted odds ratios with 95% confidence intervals (95% CI) were derived as measures of effect and precision. A p value of < 0.05 was considered statically significant. The analyses were performed using Stata 15 (Stata Corp. 2017. Stata Statistical Software: Release 15. College Station, TX: Stata Corp LLC.) and G-Power 3.1.7.

Results

General characteristics of the study population

One-hundred and forty-one WCA were interviewed: 42.6% ($n = 60$) and 57.4% ($n = 81$), respectively, lived in urban and peri-urban areas (wards). Demographic, social, educational and economic characteristics of the sample are described in Table 1.

Urban (UW) and peri-urban women (PUW) were similar, except for age class distribution ($p < 0.001$); the majority of UW women (88.3%) were between 20 and 34 years of age,

Table 1 General characteristics of the study population.

	Total <i>n</i> = 141 (%)	Urban <i>n</i> = 60 (%)	Peri-urban <i>n</i> = 81 (%)	<i>p</i> (Urban vs. peri-urban)
Level of education				
No education	7 (5.0)	3 (5.0)	4 (4.9)	[§] ns
Primary + secondary	101 (71.6)	48 (80.0)	53 (65.4)	[§] ns
High school (level A) + technical + certificate + diploma + graduation	33 (23.4)	9 (15.0)	24 (29.6)	[§] ns
Religion				
Muslims	38 (26.9)	19 (31.7)	19 (23.5)	*ns
Christians	102 (72.3)	41 (68.3)	61 (75.3)	*ns
Lutherans	1 (0.7)	–	1 (1.2)	*ns
Vulnerability (widow or single and/or disabled and or caretakers of someone or more disabled resident in the household)				
Yes	54 (38.3)	27 (45.0)	27 (33.3)	*ns
No	87 (61.7)	33 (55.0)	54 (66.7)	*ns
Following a prescribed diet				
Yes	32 (22.7)	15 (25.0)	17 (21.0)	*ns
No	109 (77.3)	45 (75.0)	64 (79.0)	*ns
	Median (IQR)	Median (IQR)	Median (IQR)	<i>p</i>
Money spent weekly for food (TZS schilling)	28,000.0 (20,000.0–40,000.0)	28,000.0 (20,000.0–35,000.0)	25,000.0 (18,500.0–50,000.0)	[^] ns

Frequency data are reported as absolute numbers and percentages: *n* (%). Quantitative data are reported as median and inter-quartile range: median (IQR). Statistical significance threshold: *p* = 0.05. Not significant is reported as 'ns'. Data are reported as absolute number and frequency (percentage).

[§]Tests applied: Fisher exact test.

*Tests applied: Chi-square test.

[^]Tests applied: Mann–Whitney *U* test.

while, among PUW, young women (<24 years) and middle-aged women (>40 years) were both represented (38.3 and 21%, respectively).

Educational level was comparable (*p* = 0.12), even if, among women living in a peri-urban area, 29.6% had a diploma (high school—level A or technical certificate or diploma or graduation), compared to 15% of the UW. The sample was composed of 72.3% of Catholics, 27% of Muslims and one Lutheran woman (0.7%).

The vulnerability was described in 61% of women with no significant difference between UW and PUW.

Finally, women spent in median 28,000.0 (IQR: 20,000.0–40,000.0) Tanzania shillings weekly for food and 22.7% of the sample was following a diet prescribed by a nutrition expert. For both variables, no differences were found between UW and PUW (Table 1).

Indigenous vegetable consumption

Vegetable Amaranths and African Nightshade were the most IV consumed; however, only 16% (*n* = 23) of the sample consumed at least one portion of IVs per day.

39.2% (*n* = 9) and 47.8% (*n* = 11) of the volunteers consumed, respectively, either Vegetable Amaranths or African Nightshade while merely 1.03% of women (*n* = 3) usually consumed both species. UW consumed significantly more IV than PUW (74% vs. 26%; *p* = 0.001, respectively).

(All this information was extrapolated from the 24-hR).

MDD-W index calculation

Total median MDD-W index was 4.0 (IQR. 3.0–5.0) and micronutrient adequacy (MDD-W index ≥5) was achieved by 44% of the whole sample.

Table 2 shows the different food groups consumption used for the MDD-W index calculation. The most consumed group was 'grains, white roots and tubers and plantains' (100%) while 'nuts and seeds' (11.3%) and 'eggs' (7.1%) were the most limited ones. Particularly, UW consumed significantly more 'other vitamin-A-rich fruits and vegetables' and 'other vegetables' than PUW (53.3% vs. 32.1%, *p* = 0.01 and 60.0% vs. 42.0%, respectively; *p* = 0.03).

Table 2 Description of food groups consumption used for the MDD-W index calculation.

Food groups	Total <i>n</i> = 141 (% consumed)	WARD		<i>p</i> (Urban vs. peri-urban)
		Urban <i>n</i> = 60 (% consumed)	Peri-urban <i>n</i> = 81 (% consumed)	
(1) Grains, white roots and tubers, and plantains	141 (100)	60 (100)	81 (100)	ns
(2) Pulses (beans, peas and lentils)	52 (36.9)	21 (35.0)	31 (38.3)	ns
(3) Nuts and seeds	16 (11.3)	6 (10.0)	10 (12.3)	ns
(4) Dairy	46 (32.6)	16 (26.7)	30 (37.0)	ns
(5) Meat, poultry and fish	83 (58.9)	34 (56.7)	49 (60.5)	ns
(6) Eggs	10 (7.1)	5 (8.33)	5 (6.2)	ns
(7) Dark green leafy vegetables	47 (33.3)	21 (35.0)	26 (32.0)	ns
(8) Other vitamin-A-rich fruits and vegetables	58 (41.1)	32 (53.3)	26 (32.1)	0.01
(9) Other vegetables	70 (49.6)	36 (60.0)	34 (42.0)	0.03
(10) Other fruit	79 (56)	29 (48.3)	50 (61.8)	ns

Frequency data are reported as absolute numbers and percentages: *n* (%). Statistical significance threshold: *p* = 0.05. Tests applied: Chi-square test, not significant is reported as ns. Data are reported as absolute number and frequency (percentage).

Factors related to micronutrient adequacy

Table 3 shows median MDD-W index related to IV consumption and other different demographic, social and educational characteristics.

Particularly, women who usually consumed IV reported a higher median MDD-W index than those who did not (median: 5.0, IQR: 4.0–5.0 vs. median 4.0, IQR: 3.0–5.0; *p* = 0.03, respectively), furthermore, Catholic women had a higher median MDD-W index than Muslim ones (median: 5.0, IQR: 3.0–5.0 vs. median: 4.0, IQR: 3.0–5.0; *p* = 0.02, respectively). On the contrary, age class, type of ward, vulnerability, level of education and being on a diet were not significantly associated with a variation of MDD-W index. A weak positive correlation (*r* = 0.13, *p* = 0.12) was reported between MDD-W index and money spent weekly on food.

Moreover, in Table 4, we estimated the effect of each predictor on MDD-W index variation; the mutually adjusted effects of the predictors, that were statistically significant in the exploratory analyses, were also estimated.

IV consumption resulted significantly and independently associated with MDD-W index; in women who consumed IV MDD-W index was 0.66 points (95% CI: 0.02–1.30, *p* = 0.046) higher than in those who did not. The catholic religion seemed also independently related to an average increase of 0.50 points MDD-W index with respect to the Muslim religion, although this difference was only borderline significant (95%CI: −0.039–1.038, *p* = 0.069).

Finally, considering micronutrient adequacy DD (MDD-W index ≥ 5) as an expected outcome, including IV consumption and religion as mutually adjusted predictors, we observed in women consuming IV three times higher odds than in those not consuming IVs (OR: 3.30, 95% CI: 1.24–8.81, *p* = 0.017), while catholic women had twice the

odds (OR: 2.75, 95% CI: 1.19–6.35, *p* = 0.018) compared to Muslim ones.

Discussion

This study aimed at identifying possible contributors to micronutrient adequacy, including demographic, social, educational and economic variables, and IV consumption among WCA living in urban and peri-urban areas of Arusha (Tanzania).

The IV consumption was significantly and independently associated with the MDD-W index. In fact, in women who consumed IV, the MDD-W index was 0.66 points (95% CI: 0.02–1.30, *p* = 0.046) higher than those who did not.

The MDD-W is a food group diversity indicator developed at national and subnational levels to reflect one key dimension of diet quality such as the micronutrient adequacy [9].

The MMD-W index referring to the whole cohort of women and calculated from data obtained by 24-hR [9], scored 4, below the cut-off (MDD-W ≥ 5). Our data showed that micronutrient adequacy was achieved only by 44% of the sample, with an increased risk of inadequate micronutrient intake, and thus vulnerability to food insecurity [17]. This finding was in agreement with the results described by Bellows et al. [17] reporting that only 10% of WCA in rural Tanzania had an MDD-W index higher than five. Particularly, analyzing the food groups for the MDD-W index calculation, we observed that women had a prevalent-based-starchy food diet since the entire sample consumed daily ‘grains, white roots and tubers’. These findings are consistent with those reported by several other authors [17], describing that cereals and starchy foods, especially maize-based foods, are the most consumed foods in Sub-Saharan Africans.

Table 3 Description of MDD-W index in relation to different characteristics.

MDD-W index						
Ward						
UW (<i>n</i> = 60)		PUW (<i>n</i> = 81)		<i>p</i>		
4.0 (3.0–5.0)		4.0 (3.0–5.0)		*ns		
IV Consumption						
Yes (<i>n</i> = 23)		Not (<i>n</i> = 118)		<i>p</i>		
5.0 (4.0–5.0)		4.0 (3.0–5.0)		*0.02		
Religion						
Catholic (<i>n</i> = 102)		Muslims (<i>n</i> = 38)		<i>p</i>		
5.0 (3.0–5.0)		4.0 (3.0–5.0)		*0.02		
Vulnerability						
Yes (<i>n</i> = 54)		Not (<i>n</i> = 87)		<i>p</i>		
4.0 (3.0–5.0)		5.0 (3.0–5.0)		*ns		
Level of education						
No education (<i>n</i> = 7)		Primary or secondary (<i>n</i> = 101)		High school (level A) or technical or certificate or diploma or graduation (<i>n</i> = 33)		<i>p</i>
4.5 (4.0–5.0)		4.0 (3.0–5.0)		4.0 (3.0–5.0)		^ns
Prescribed diet						
Yes (<i>n</i> = 32)		Not (<i>n</i> = 109)		<i>p</i>		
5.0 (3.5–5.0)		4.0 (3.0–5.0)		*ns		
Age class (years = Y)						
14–19 y (<i>n</i> = 3)	20–24 y (<i>n</i> = 44)	25–29 y (<i>n</i> = 37)	30–34 y (<i>n</i> = 22)	35–39 y (<i>n</i> = 14)	40–44 y (<i>n</i> = 21)	<i>p</i>
5.0 (4.0–5.0)	4.0 (3.0–5.0)	4.0 (3.0–5.0)	4.5 (4.0–6.0)	4.0 (2.0–5.0)	5.0 (3.0–5.0)	*ns

Quantitative data are reported as median and inter-quartile range: median (IQR). Statistical significance threshold: $p = 0.05$. Not significant is reported as 'ns'. Data are reported as median (IQR).

*Tests applied: Mann–Whitney *U* test.

^Tests applied: Kruskal–Wallis test.

Besides, the analysis of food groups by wards revealed that UW consumed significantly more 'other vitamin-A-rich fruits and vegetables' and 'other vegetables' than PUW. This, as already reported above for the IV consumption, could be due to greater access to food in different markets in the urban areas than in the peri-urban one.

MDD-W index was then related to other factors, included IV consumption (Table 3). Addressing micronutrient deficiency with traditional African vegetables (previously named IV) could represent a sustainable way to prevent micronutrient malnutrition, mostly underdiagnosed, particularly in poor urban and rural households [18], providing low-cost high-quality diet to a large population segment [19]. IV are an important source of nutrients including, minerals, antioxidants, fibre and prebiotics [19, 20], essential components of a balanced and healthy diet, especially for vulnerable groups, such as infants and WCA [1]. To the best of our knowledge, this is the first observational study evaluating the impact of IV consumption in the micronutrient adequacy, in Tanzanian WCA [21].

In the present research surprisingly, although Amaranth is the most popular leafy vegetable cultivated by 67% of the

households living in Dar er Salaam [22] and is one of the most consumed and easy to find in all Arusha region markets, together with African nightshade [21], only 16% of volunteers consumed at least one portion of IV per day of either Amaranths or African Nightshade and almost 1% of the sample habitually consumed both species [22, 23]. Moreover, UW consumed significantly more IV than PUW. High consumption could be explained because people living in the city of Arusha have a wider choice of food products than people living in peripheral areas. In fact, at the urban level, especially in the Municipal Council of Arusha, accessibility to food markets is higher compared to peri-urban and rural areas, where markets are held once a week. Peri-urban dwellers tend to have more land available to establish home gardens [11, 22].

Women who habitually consumed IV reported a higher median MDD-W index than those who did not and the IV consumption resulted significantly and independently associated with MDD-W index. Besides, considering as the outcome an adequate DD (MDD-W index ≥ 5) it is been highlighted that women consuming IV had an odds ratio of more than three times compared to women not consuming IV.

Table 4 Unadjusted and mutually adjusted associations of MDD-W index with demographic, social or educational characteristics.

MDD-W index	Linear regression models		Multivariable linear regression model	
	β (95% CI)	<i>p</i> value	β adj. (95% CI)	<i>p</i> value
Age class	0.017 (−0.15–0.18)	0.84		
5 years change (age 14–44)				
Level of education				
Primary + secondary education vs. no education	−0.092 (−1.22–1.03)	0.872		
High level education vs. no education	−0.399 (−1.60–0.80)	0.513		
Religion	0.553 (0.01–1.09)	0.046	0.50 (−0.039–1.039)	0.069
Catholic vs. Muslim				
Vulnerability	−0.317 (−0.81–0.18)	0.21		
Yes vs. no				
Ward	0.11 (−0.38–0.60)	0.655		
UW vs. PUW				
IV Consumption	0.717 (0.07–1.36)	0.03	0.657 (0.02–1.30)	0.046
Yes vs. no				
Following a prescribed diet	0.177 (−0.40–0.76)	0.547		
Yes vs. no				
Money spent weekly for food	0.0105 (0.003–0.024)	0.122		
1000 TZS schilling change				

Linear regression models were applied to estimate unadjusted Beta coefficients for each MDD-W predictor and 95% confidence intervals (β and 95% CI), whereas a multivariable linear regression model was applied to estimate mutually adjusted beta coefficients (β adj. and 95% CI) using the predictors resulted statistically significant in the explorative models (at $p < 0.10$ level).

Surprisingly, religion was another important factor significantly influencing MDD-W index, being Catholic women scored a higher median MDD-W index and recorded an odds ratio higher of more than two to have adequate DD than the Muslim ones.

Unlike what might have been expected, there was no statistically significant difference between ‘no education’, ‘money spend for food’ and ‘primary or secondary’ education group related to MDD-W index. The result obtained could be linked to the sample size, leading to the unrepresentative result of the women in the population. Although the present study was the first one evaluating the impact of IV consumption in the DD of WCA, some limitations should be acknowledged.

An important consideration is related to the geographical areas of data collection: WCA interviewed in the present research were not representative of the Arusha region and Tanzania, in terms of demographic, social, educational and economic variables. To have a more representative picture of the Tanzanian population, the study population should have been extended and food habits and MDD-W index in rural areas should have been also evaluated. At last, the difference in IV consumption between UW and PUW described above, could be also justified by the food habits variation connected to the season. Tanzania is characterized by two rainy seasons; the short rains are generally from October to December, while the long rains last from March to June. The central plateau tends to be dry and arid

throughout the year. During the different seasons, food habits change in relation to the accessibility of food [24]. For this reason, data collected during the dry season, from June to August, could be a limit of the study.

In conclusion, insufficient intake of micronutrients in childbearing age is a major challenge to address, as it can primarily affect women and could potentially compromise the ‘critical windows’ of preconception and conception, negatively affecting pregnancy outcome. Increasing dietary diversity is one of several approaches to improving micronutrient intake. The MDD-W used in the present research is an indicator of food group diversity that reflects the adequacy of micronutrients [9]. Proper management and use of biodiversity, such as IV consumption, is likely to address micronutrient inadequacies, as demonstrated in our study by the positive association between IV consumption and MDD-W index. Therefore, the intervention on the food basket promises to reduce micronutrient deficiencies [25], especially in the most vulnerable population groups such as WCA, with possible positive impact also on offspring and future children [25]. Health authorities should recommend adults to include IV in their diets to promote micronutrient adequacy and ensure better health through a wide range of valuable health outcomes.

Acknowledgements The authors are very grateful to Dr Silvia Maffoni for the help in the data collection and to Dr Marco Gnesi for the statistical consultation.

Funding Study approval was granted by the Sokoine University of Agriculture (SUA). To facilitate the research function, the Vice-Chancellor of the SUA was empowered to issue research clearance to staff, students, research associate and researchers of SUA on behalf of the Tanzania Commission for Science and Technology (Registration number: DPRTC/R/142 Val. II/10) within the ‘Sustainable Agri-Food Systems Strategies (SASS)’ project, funded by the Italian Ministry of University and Research (MIUR) (Fondo Integrativo Speciale per la Ricerca, FISIR; CUP: H42F16002450001).

Author contributions Each author has participated actively in the work and has given substantial contribution. MVC, RDG, AGM, NHM and HC conceived and designed the work that led to the submission; MVC, AGM and NHM acquired data; MCM, MVC and RDG played a role in the statistical analysis; all the authors were involved in interpreting the results; MVC, RDG and MCM drafted the manuscript; SC, JM and HC revised the manuscript. All the authors agreed to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. Each author has read and approved the final submitted manuscript.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

Publisher's note Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

References

- Conti M, Campanaro A, Coccetti P, De Giuseppe R, Galimberti A, Labra M, et al. Potential role of neglected and underutilized plant species in improving women's empowerment and nutrition in areas of sub-Saharan Africa. *Nutr Rev*. 2019;77:817–28. <https://doi.org/10.1093/nutrit/nuz038>.
- Wrottesley S, Lamper C, Pisa P. Review of the importance of nutrition during the first 1000 days: maternal nutritional status and its associations with foetal growth and birth, neonatal and infant outcomes among African women. *JDOHD*. 2016;7:144–62. <https://doi.org/10.1017/S2040174415001439>.
- Rivera M, Alvarez I. From a market approach to the centrality of life: an urgent change for women. In: *Right to food and nutrition watch*. 2017. p. 36–41.
- FAO. Guidelines for measuring household and individual dietary diversity. FAO; 2013.
- Jones AD. Critical review of the emerging research evidence on agricultural biodiversity, diet diversity, and nutritional status in low- and middle-income countries. *Nutr Rev*. 2017;75:769–82. <https://doi.org/10.1093/nutrit/nux040>.
- Lachat C, Ranieri JE, Walker SK, Kolsteren P, Van Damme P, Verzele K, et al. Dietary species richness as a measure of food biodiversity and nutritional quality of diets. *PNAS*. 2018;115:127–32. <https://doi.org/10.1073/pnas.1709194115>.
- Ochieng J, Afari-Sefa V, Lukumay PJ, Dubois T. Determinants of dietary diversity and the potential role of men in improving household nutrition in Tanzania. *PLoS ONE*. 2017;12:e0189022. <https://doi.org/10.1371/journal.pone.0189022>.
- Chitambo O, Haukeland S, Fiaboe KK, Grundler FMW. African nightshade and African spinach decrease root-knot nematode and potato cyst nematode soil infestation in Kenya. *Plant Dis*. 2019;103:1621–30. <https://doi.org/10.1094/PDIS-07-18-1193-RE>.
- FAO and FHI 360. 2016. Minimum dietary diversity for women: a guide for measurement. Rome: FAO.
- Tanzania Government Profile. Index Mundi. 2019. https://www.indexmundi.com/tanzania/government_profile.html.
- Borrelli N, Ndakidemi P. Small farmers for a food system transition: evidence from Kenya and Tanzania. *Ledizioni*; 2020.
- Gitagia MW, Ramkat RC, Mituki DM, Termote C, Covic N, Cheserek MJ. Determinants of dietary diversity among women of reproductive age in two different agro-ecological zones of Rongai Sub-County, Nakuru, Kenya. *Food Nutr Res*. 2019;63. <https://doi.org/10.29219/fnr.v63.1553>.
- Lukmanji Z, Hertzmark E, Mlingi N, Assey V, Ndossi G, Fawzi W. Tanzania food composition tables. MUHAS- TFNC, HSPH, Dar es Salaam Tanzania; 2008. <http://www.hsph.harvard.edu/nutritionsource/more/food-tables/index.html>.
- Gibson RS, Charrondiere UR, Bell W. Measurement errors in dietary assessment using self-reported 24-hour recalls in low-income countries and strategies for their prevention. *Adv Nutr*. 2017;8:980–91. <https://doi.org/10.3945/an.117.016980FAO>.
- Gonete KA, Tariku A, Wami SD, Akalu TY. Dietary diversity practice and associated factors among adolescent girls in Dembia district, northwest Ethiopia, 2017. *Public Health Reviews*. 2020;41:23.
- Mubarik A, Tsou S. Combating micronutrient deficiencies through vegetables—a neglected food frontier in Asia. *Food Policy*. 1997;22.1:17–38.
- Bellows AL, Canavan CR, Blakstad MM, Mosha D, Noor RA, Webb P, et al. The relationship between dietary diversity among women of reproductive age and agricultural diversity in rural Tanzania. *Food Nutr Bull*. 2019. <https://doi.org/10.1177/0379572119892405>.
- Ochieng J, Afari-Sefa V, Karanja D, Kessy R, Rajendran S, Samali S. How promoting consumption of traditional African vegetables affects household nutrition security in Tanzania. *Renew Agriculture Food Syst*. 2018;33:105–15. <https://doi.org/10.1017/S1742170516000508>.
- Chweya JA, Eyzaguirre PB. The biodiversity of traditional leafy vegetables. University of Nairobi; 1999.
- Bvenura C, Afolayan AJ. The role of wild vegetables in household food security in South Africa: a review. *Food Res Int*. 2015;76:1001–11.
- De Putter H, Van Koesveld MJ, De Visser CLM. Overview of the vegetable sector in Tanzania. *Afriveg*. 2007. <http://hdl.handle.net/20.500.12018/7338>.
- Blakstad MM, Bellows AL, Mosha D. Neighbour home gardening predicts dietary diversity among rural Tanzanian women. *Public Health Nutr*. 2019;22.9:1646–53.
- Gamuchirai C, Shackleton C. Minimum dietary diversity indexes for women indicate micronutrient adequacy and food insecurity status in South African towns. *Nutrients*. 2017;9:812.
- Mazengoa MC, Simellc O, Lukmanjid Z, Shirimad R, Karvetti RL. Food consumption in rural and urban Tanzania. *Acta Tropica*. 1997;68:313–26.
- Mshanga N, Martin H, Petrucka P. Food-basket intervention to reduce micronutrient deficiencies among Maasai-pregnant women in Tanzania: a quasi-experimental study. *J Hum Nutr Diet*. 2019;32:625–34.