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Nutritional profiling of *Moringa oleifera* leaves and seeds from three selected districts in Tanzania

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Abstract

The leaves and seeds of *Moringa oleifera* are known to have immense nutritional value. This study was carried out to evaluate the nutrient composition and properties of *M. oleifera* leaves and seeds in Tanzania. Seed and leaf samples were collected from the Simanjiro, Kilolo, and Mpwapwa districts in Kilimanjaro, Iringa, and Dodoma regions respectively. A cross-sectional research design was used in this study to collect seeds and leaves samples. Analysis of Variance indicated a significant difference ($p<0.05$) in the concentration of macronutrients in the leaves and seeds of *M. oleifera*. The amount of water, crude fibers, and ash concentrations was higher in the leaves than in the seeds. However, the concentration of proteins and lipids was higher in seeds compared to the leaves. Significant differences were observed in the water content, crude fiber in leaves and seeds in the three regions ($p<0.05$). There was no significant difference in protein and lipid contents in seeds from the three studied regions ($p>0.05$). A macronutrient composition indicated a high concentration of Zn, Fe, Ca, P, and Bk in leaves compared to the seeds from all three regions. It was noted that K and P had higher concentrations in the seeds than in the leaves. Moreover, the leaves and seeds collected from Iringa region contained higher concentrations of macronutrients compared to those from Dodoma and Kilimanjaro regions. These findings indicate that *M. oleifera* leaves and seeds are rich in vital amounts of nutritional components, hence, presents a promising balance of food ingredients for human and animal diets. Cognizant of this, *M. oleifera* leaves and seeds can be used to combat malnutrition, especially among infants and nursing mothers. For further scale-ups, the alteration of macronutrients could play a key role in the yield and quality of *M. oleifera* in agricultural systems.

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Introduction

The Moringaceae is a single-genus family with 13 known tree species (Khawaja *et al.*, 2010; Senthilkumar *et al.*, 2018). The most known and used are two tree species including *Moringa oleifera* Lam and *M. stenopetala* (Baker f) Cufod. The trees are native to India. In East Africa, these trees offer a strong potential option for agroforestry. *Moringa oleifera* is a fast-growing, perennial, deciduous tree that can reach a height of 10 - 12 m and a trunk diameter of 45 cm (Parrotta, 1993). The tree species have a variety of potential uses due to their nutritional and medicinal properties as well as industrial purposes (Dhakad *et al.*, 2019).

Almost all parts of the plant like the pods, seeds, leaves and flowers have value for food and medicinal values. The leaves are nutritious for human consumption with a high concentration of crude protein and other essential elements (Gidamis *et al.,* 2003). Its seeds are also reported to be important for human consumption as they contain about 35 - 40% oil, which can be used in many ways, including for human consumption, lubrication of machinery, hairdressing and manufacturing of perfumes (Odeyinka *et al.,* 2007). The seed oil, therefore, has a high potential market value that can be a source of income for *Moringa* growers (Maroyi, 2006). All parts of the tree are used medically and appear to have potent antioxidant, chemopreventive and glucoregulatory activity. In a study conducted in Ugandan communities, people used *M. oleifera* leaves to reduce the symptoms of diabetes, hypertension, HIV/AIDS-related symptoms, and to treat worms in both humans and animals (Kasolo *et al.*, 2010). In addition, M. *oleifera* is anti-inflammatory, anti-depressant, cell proliferation inhibition, and anti-cancer. It also cures stomach aches and ulcers (Abdul Razis *et al.*, 2014; Kumar, 2017; Popoola and Obembe, 2013).

Moringa leaves and seeds have been reported contain both macro and micro nutrients, having a significant source of vitamin C, beta-carotene, calcium, protein, potassium and iron (Siddhuraju and Becker, 2003). A study by Jed, 2005 shown *M. oleifera* leaves contain more vitamin C than oranges, more vitamin A than carrots, more potassium than bananas, more calcium than milk, more protein than of milk and egg and more iron than spinach. On the other hand, Moringa seed kernels contain a substantial amount of oil. Moringa seeds have antimicrobial activity against bacteria and fungi (Bharali *et al.,* 2023; Cárceres *et al.*, 1992). It is also having the larvicidal activity against the mosquito that spreads dengue and yellow fever (Gupta *et al.* 1999). The tree is valuable to human and animals' nutritional. Although *Moringa oleifere* is one of the important trees for nutritional and medicinal purposes, there is a variation in the quantity and quality of micro and micronutrients of the tree species in leaves as well as seeds in different areas of locality (Nouman *et al.*, 2014). Many studies have been conducted to prove the usefulness of Moringa leaves and seeds such as anti-inflammatory, antipyretic, analgesic, wound healing, antihypertensives, anti-diabetic, anticancer, antiasthma, anti-arthritis, anti-epileptic, antianemia, antiviral, and many more Mun'im *et al* 2016., Martínez-González *et al.,* 2017. Studies have shown that there is a wide variation in the nutritional content of leaves and seeds depending on the species type, provenance, environmental conditions, and age of Moringa tree species in the world Dao and Kabore (2015). Many studies on the nutritional information of Moringa leaves are provided in several countries such as India, Ghana, Sudan, Pakistan including Tanzania. For example, in Pakistan, its varieties have been tested for the nutritional composition of their leaves in different locations and showed variations in the nutritional compositions (Iqbal and Bhanger, 2006). However, little is known on the variation of micro and micro nutrient composition between seed and leaves of the *M. oreifera*. Understanding the variation of macro and micro-nutritional Moringa seeds and leaves in different regions is crucial for its optimal uses.

Therefore, this study aimed to analyze the variation of nutritional contents of *M. oleifera* leaves and seeds from three selected districts in Tanzania. Specifically, this study investigated the variation of macro and micro-nutritional contents of *M. orifera* seeds and leaves in the selected regions. The study provides information on the best part of *M. oleifera to* be used for nutrients and specifies which Moringa tree species in Tanzania have the most nutritional value.

Materials and methods

Study area description

The study was carried out in Iringa, Dodoma and Kilimanjaro regions in Tanzania (Fig. 1).

Sees and leaves samples were collected in Kilolo District (Iringa), Mpwapwa District (Dodoma) and Simanjiro Meru District (Kilimanjaro). The selection of study sites was based on the development of Moringa farms initiated by earlier projects in the represented districts.

The annual rainfall range in the study site is between 500 and 800 mm, and the average temperatures range from 25°C to 30°C.

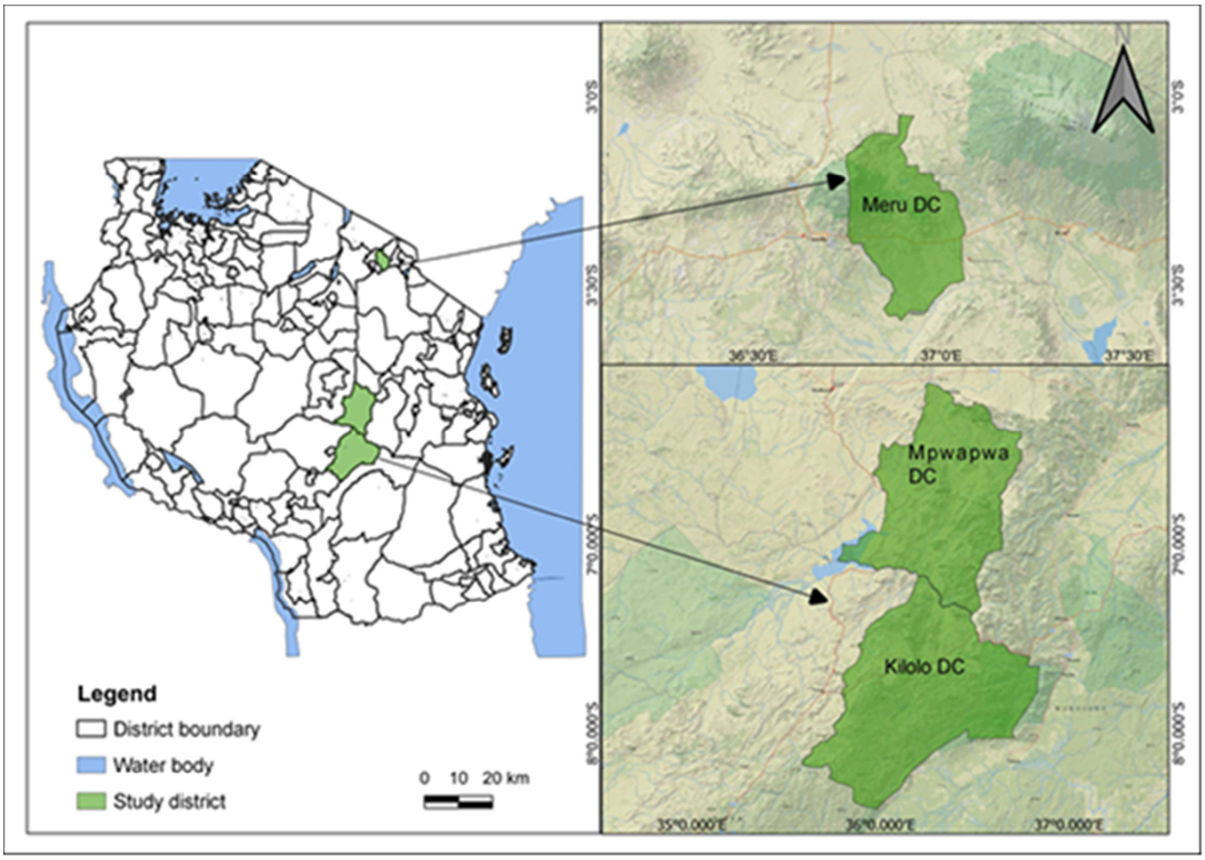

Fig. 1. Map showing three districts where seeds and leaves of *Moringa oleifera* samples were collected

Study design, sample collection and processing

A cross-sectional research design was used in this study. The seeds and leaves samples were collected during the end of wet season in May 2023. Three farms from each district were purposively selected, where five trees were randomly selected for the collection of leaf samples and seed pods for nutritional content analysis. In each sampled tree ten leaves at and ten seed pods were selected for the processing of the sample. The samples were oven dried at 65° C and grounded to obtain the powder which was used in the analysis of micronutrients and macronutrients. The samples were kept in air-tight plastic bags at room temperature (30° C) for further analysis. Then Moringa leaf and seeds samples (5 grams, each) in triplicates were used for determination of moisture content by weighing in a crucible and drying in oven at 105 °C for 24 hours until a constant weight was obtained. The samples were redy for the micro and micro analysis. The selection criterion was the Moringa tree from mixed farming and their seed sources were from the same source. The collection of seeds and leaves was done from mature trees of 13 years. Then, the collected seeds and leaf samples were sent to the Sokoine University of Agriculture (SUA) for quantification of nutritional contents.

Nutritional contents analysis

Micronutrient and micronutrient analyses were conducted in leaf and seed samples. The seeds and leaves were analysed for their moisture contents, lipids, protein, crude fibre and ashes. The crude fibre was converted into fatty acid by multiplying with a conversion factor of 0.80 as described by Akinyeye *et al.* (2010; 2011) and Greenfield and Southgate (2003). Protein contents were determined using the Kjeldah method (AOAC, 1990) by multiplication of its Kjeldahl nitrogen content by a factor of 6.25 (Ogbe *et al.,* 2011). Analysis of ash content was done by ashing at 550 ^{o}C for about 3h. The crude fibre content of the samples was determined by digestion method and the lipid was done by Soxhlet extraction method according to the Association of Official Analytical Chemists (AOAC) (1990). The macronutrients analysed in leaves and seeds were Zinc (Zn), Iron (Fe), Calcium (Ca), Magnesium (Mg), Potassium (K), Sodium (Na), Phosphorus (P), and beta-carotene (β-carotene). The Zn, K, Na, Mg, Ca, and B carotene were determined using the atomic absorption spectrophotometer (AAS-Buck 205), as described in the methods of the AOAC (1990). Phosphorus was determined calorimetrically (AOAC, 1990). All micronutrient analysis of seeds and leaves samples of *M. oleifera* was determined after the sample mineralization by humid voice according to Houba *et al.* method (1989). All the determinations were also done in triplicates and the proximate values were presented in percentages.

Statistical analysis

Descriptive statistics was used for data analysis (Olawuyi, 1996). The means and standard deviation of statistical values were calculated. Student *t*-test was used to compare the variation in nutritional contents between leaves and seeds across three sites. Analysis of variance (ANOVA) was performed to compare the means in nutritional compositions in the three districts. The means were separated using the new Duncan's multiple range test and $p < 0.05$ was applied to establish significant differences.

Results and discussion

Variation of the macronutrient composition of M. oleifera leaves and seed samples in three sites

The macronutrient compositions of *M. oleifera* analyzed in this study included water, protein, lipids, crude fibres and ash contents. The leaves and seed macronutrient composition analysis showed significant concentrations in macronutrient concentration (Table 1). No significant differences were observed in the macronutrient compositions in seeds and leaves in the three sites ($p > 0.05$). This might be because the same Moringa germplasm was distributed by the same organizations responsible for raising awareness about planting Moringa trees in all three regions. The macronutrient compositions from the edible parts of plants may vary according to biotic and abiotic conditions of the environment where they are grown, as well as maturity (Melo *et al.*, 2013). The results obtained in this study are the same as the ones reported by Sanchez–Machado *et al.* (2010).

Water content in M. oleifera leaves and seed samples

The results showed that the *M. oleifera* leaves had a higher concentration of water than the seeds (Table 1). Similar results were observed by Melo *et al.* (2013) who also reported higher water content in leaves than in seeds. The total mean water contents of *M. oleifera* for the three regions were 63.72 ± 1.28 mg/100g. It was observed that the mean concentration of water (mg/100g) in three regions was 62.79 ± 0.83 mg/100g, 64.55 ± 1.17 mg/100g and 63.81 ± 1.25 mg/100g in Kilimanjaro, Dodoma and Iringa, respectively. There was a significant difference in water contents in the leaf samples between the three regions ($F_{2, 29} = 6.454$, $p = 0.005$). Furthermore, the results showed that the average seed water content (mg/100g) in the seeds of *M. oleifera* was 6.10 ± 0.04 mg/100g, 6.68 ± 0.51 mg/100g and 6.64 ± 0.29 mg/100g in Kilimanjaro, Dodoma and Iringa, respectively. No significant difference was observed in the seed water content among the three studied regions ($F_{2, 29}$ = 1.343, p = 0.291). The higher amount of water observed in the leaves was due to the photosynthetic process that occurs in leaves.

Table 1. Micronutrient composition characterization of the *Moringa oleifera* leaves and seed samples

Regions	Components	Leaves (mg/100g)	Seeds (mg/100g)
Kilimanjaro	Water	62.79 ± 0.83	6.10 ± 0.04
	Proteins	13.89 ± 0.79	29.45 ± 0.16
	Lipids	2.32 ± 0.49	30.99 ± 0.06
	Crude fibres	3.79 ± 0.46	0.93 ± 0.028
	Ashes	8.82 ± 0.55	2.37 ± 0.36
Dodoma	Water	64.55 ± 1.17	6.68 ± 0.51
	Proteins	14.65 ± 0.39	32.04 ± 1.57
	Lipids	2.31 ± 0.15	32.27 ± 2.58
	Crude fibres	3.67 ± 0.46	2.15 ± 0.73
	Ashes	8.67 ± 0.82	2.26 ± 0.73
Iringa	Water	63.81 ± 1.25	6.64 ± 0.29
	Proteins	14.11 ± 0.57	28.36 ± 0.29
	Lipids	2.55 ± 0.28	32.16 ± 3.80
	Crude fibres	2.30 ± 0.25	2.90 ± 0.19
	Ashes	8.42 ± 0.50	3.22 ± 0.58
Mean	Water	63.72 ± 1.28	6.60 ± 0.47
	Proteins	14.22 ± 0.67	30.93 ± 3.09
	Lipids	2.39 ± 0.34	32.10 ±1.39
	Crude fibres	3.26 ± 0.88	2.18 ± 0.81
	Ashes	8.53 ± 0.53	2.491± 0.53

Protein content composition in M. oleifera leaves and seed samples

The overall average protein content in *M. oleifera* Leaves and seeds for the three regions was 14.22 ± 0.67 mg/100g. The mean protein content composition for the *M. oleifera* leaves was 13.89 ± 0.79 mg/100g, 14.65 ± 0.39 mg/100g and 14.11 ± 0.57 mg/100g in Kilimanjaro, Dodoma and Iringa respectively. No significant difference was observed among the leaves' protein content in the three regions ($F_{2, 29}$ = 4.169 p = .026). Additionally, the mean protein contents in *M. oleifera* seeds for Kilimanjaro, Dodoma and Iringa were 32.04 ± 1.57 mg/100g, 28.36 ± 0.29 mg/100g and 28.36 ± 0.29 mg/100g, respectively. Generally, higher protein contents were observed in the seeds than in leaves but no significant difference was observed in the seed protein content in the three regions $F_{2, 29}$ = 2.940, p = 084). Similar results were observed by Anwal and Muhammad (2005) who found a higher content of protein (34%) and lipids (23%) contents in seeds than the contents observed in other parts as the seeds.

Lipids content in M. oleifera leaves and seed samples

It was observed that the total average concentration of lipids in the *M. oleifera* leaf samples from three regions was 2.39 ± 0.34 mg/100g. The mean concentration of lipids for the leaf samples from three regions were 2.32 ± 0.49 mg/100g, 2.31 ± 0.15 mg/100g and 2.55 ± 0.28 mg/100g in Kilimanjaro, Dodoma and Iringa, respectively. The seed's lipid content for the three regions was 30.99 ± 0.06 mg/100g, 32.27 ± 2.58 mg/100g and 32.16 ± 3.80 mg/100g in Kilimanjaro, Dodoma and Iringa, respectively. No significant difference was observed in the lipid content in *M. oleifera* leaves from the three regions ($F_{2, 29}$ =1.672 p = 0.207). The seed's lipid content for the three regions was 30.99 ± 0.06 mg/100g, 32.27 ± 2.58 mg/100g and 32.16 ± 3.80 mg/100g in Kilimajaro, Dodoma and Iringa, respectively. No significant difference was observed in the lipid content in *M. oleifera* seeds from the three regions ($F_{2, 29}$ = 699 p = 0. 513). Similarly, higher lipid content was observed in seeds compared to the leaves. This is probably because the seeds are used in storing the food produced by the leaves.

Crude fibre content in M. oleifera leaves and seed samples

The crude fibre content in *M. oleifera* leaves from Kilimanjaro, Dodoma and Iringa was 3.79 ± 0.46 mg/100g, 3.67 ± 0.46 mg/100g and 2.30 ± 0.25 mg/100g, respectively. The total mean of the leaf fibre content samples in three regions was 3.26 ± 0.88 mg/100g. A significant difference was observed in crude fibre content in *M. oleifera* in the three regions $F_{2, 29}$ = 21.3p = (0. 000). The results for the crude fibre content in *M. oleifera* seeds from the three regions were 0.93 ± 0.028 mg/100g, 2.15 ± 0.73 mg/100g and 3.22 ± 0.58 mg/100g, respectively. A significant difference was observed for the seed's crude fibre content in the three regions ($F_{2, 29}$ = 6.516 p = 0. 009). The total mean fibre content of the seeds was 2.18 ± 0.81 mg/100g. There was higher fibre content in leaves compared to seeds and a significant difference was observed for the seed's crude fibre content in the three regions ($F_{2, 29}$ =10.762 p = 001). The higher fibre contents were observed in leaves of *M. oleifera* in the tree regions. The crude fibre contents in *M. oleifera* leaves and seeds were inferentially compared to 75% reported by Anwar and Muhammad (2005).

Ash content in M. oleifera leaves and seed samples

The ash content in the leaf samples obtained from Kilimanjaro, Dodoma and Iringa was 8.82 ± 0.55mg/100g, 8.67 ± 0.82mg/100g and 8.42 ± 0.50mg/100g, respectively. The total mean of the ash content in the leaves from the three regions was 8.53 ± 0.53mg/100g. No significant difference was observed in the three districts. The seed ash content was 2.37 ± 0.36, 2.26 ± 0.73mg/100g and 3.22 ± 0.58mg/100g respectively in the three regions. The average seed ash content in the three regions was 2.491± 0.5350mg/100g. The ash contents in the *M. oleifera* leaves and seeds were inferential compared to the contents found by Anwar and Muhammad (2205) the ashes (7%).

Variation of micronutrient composition characterization of M. oleifera leaves and seed samples in three sites

Minerals are important for growth, muscle activity, skeletal development, cellular activity and oxygen transport, chemical reactions in the body, and intestinal absorption Kim and Choi (2013). In addition, minerals are required for fluid balance and nerve transmission as well as the regulation of acid-base balance Goff (2018). The micronutrient composition analysis of *M. oleifera* leaves and seeds in the present study showed remarkable concentrations in minerals and trace elements (Table 2). The results showed that the concentration of Zinc (Zn), Iron (Fe), Calcium (Ca), Potassium (K), Sodium (Na), Phosphorus (P) and BetaCarotene (β-carotene) was higher in the leaves compared to the seeds in all three regions.

Same results were obtained by Kasolo, 2010 that the leaves of *M. oleifera* are rich in minerals compered to seeds. There was no significant difference in the overall levels of the mineral elements in leaves and seeds (P > 0.05). It was further noted that K and P occurred in higher concentrations in the seeds than in the leaves. Also, it was noted that the leaves and seed samples from Iringa contained higher concentrations of the macronutrients compared to those from Dodoma and Kilimanjaro. This might be contributed to environmental factors in deferent regions.

Variation of Zink (Zn) in seed and leaves of M. oleifera

The composition of Zn in the leaf samples from Kilimanjaro, Dodoma and Iringa was 66.8 ± 3.74 mg/100 g, 67.83 ± 6.42 mg/100 g and 69.28 ± 5.52 mg/100 g, respectively. The mean concentration of Zn in leaves from all three regions was 69.28 ± 5.52 mg/100 g. A significant difference was observed in the leaf Zn content in three regions ($F_{2, 29}$ = 4.94, p = 0.15). The levels of Zn concentration in leaves are higher to the levels reported by Anjorin *et al.* (2010) who reported 18 mg/kg in Moringa leaves. It was noted that the composition of Zn in the seeds 5.08 ± 0.049 mg/100 g, 7.48 ±

1.28 mg/100 g and 7.71 ± 1.78 mg/100 g in Kilimanjaro, Dodoma and Iringa respectively. levels of Zn concentration in seeds are higher to the levels reported by Anjorin *et al.* (2010) who reported 18 mg/kg in Moringa seeds. A significant difference was observed in the composition of Zn in the leaves from the three regions ($F_{2, 29}$ = 2.970, p = 082). This different might be cause by the environmental factors to where the plant has grown. Zink (Zn) boosts the proper functioning of some enzymes and function of immune system - such as those involved in cell division, and growth.

Table 2. Macronutrients composition characterization of the *M. oleifera* leaves and seed samples

Regions	Components	Leaves (mg/100 g)	Seeds (mg/100 g)
Kilimanjaro	Zinc (Zn)	66.8 ± 3.74	5.08 ± 0 .049
	Iron (Fe)	125.58 ± 8.13	32.93 ± 0 .19
	Calcium (Ca)	2170.89 ± 11.27	980.72± 0.41
	Potassium (K)	196.72 ± 5.72	2350.480± 0.83
	Sodium (Na)	1.74 ± 0.33	1139.29 ± 2.85
	Phosphorus (P)	36.88± 2.99	11.19 ± 0 .17
	BetaCarotene (β-carotene)	32.23 ± 3.09	2.72 ± 0.16
Dodoma	Zinc (Zn)	67.83 ± 6.42	7.48 ± 1.28
	Iron (Fe)	127.57 ± 13.71	37.26 ± 6.21
	Calcium (Ca)	2120.99 ± 18.77	990.23 ± 6.84
	Potassium (K)	209.13 ± 14.82	2356.50 ± 115.8
	Sodium (Na)	1.75 ± 0 .41	990.03 ± 91.67
	Phosphor (P)	35.23 ± 2.57	13.01 ± 2.74
	BetaCarotene (β-carotene)	34.84 ± 4.81	2.743 ± 0.65
Iringa	Zinc (Zn)	73.21 ± 4.06	7.71 ± 1.78
	Iron (Fe)	123.66 ± 7.95	39.43 ± 1.65
	Calcium (Ca)	2110.27 ± 13.72	1140.50 ± 5.28
	Potassium (K)	229.83 ± 44.62	2423.66 ± 426.56
	Sodium (Na)	1.83 ± 0 .23	1043.76 ± 73.65
	Phosphorus (P)	34.38 ± 3.15	15.13 ± 1.54
	BetaCarotene (β-carotene)	32.88 ± 2.34	5.38 ± 0 .82
Mean	Zinc (Zn)	69.28 ± 5.52	7.27 ± 1.51
	Iron (Fe)	125.60 ± 10.06	37.26 ± 5.36
	Calcium (Ca)	2140.06 ± 14.68	102057 ± 8.85
	Potassium (K)	211.89 ± 29.82	2370.75 ± 204.06
	Sodium (Na)	1.77 ± 0 .32	1018.55 ± 93.99
	Phosphorus (P)	35.49 ± 3.00	13.28 ± 13.28
	BetaCarotene (β-carotene)	33.32 ± 3.63	3.33 ± 1.29

Variation of Iron (Fe) in seed and leaves of M. oleifera

The results showed that the Fe concentration in the leaves of *M. oleifera* was 125.58 ± 8.13 mg/100 g, 127.57 ± 13.71 mg/100 g and 73.21 ± 4.06 mg/100 g in Kilimanjaro, Dodoma and Iringa, respectively. The mean composition of Fe in the leaves from different regions was 69.28 ± 5.52 mg/100 g. However, no significant difference was observed in the Zn content in three distinct regions ($F_{2, 29}$ = 0.362, p = 0.700). The Fe content in the seeds was 32.93 ± 0 .19 mg/100 g, 37.26 ± 6.21 mg/100 g and 39.43 ± 1.65 mg/100 g for samples from Kilimanjaro, Dodoma and Iringa regions. Similarly, no significant difference was observed in the Fe contents the three studied regions ($F_{2, 29}$ = 0.978, p = 0.399). The Fe content in the leaves and roots is important in human and animal nutrition. According to Oluyemi *et al.* (2006), Fe was useful in preventing anaemia and other related diseases.

Variation of Calcium (Ca) in seed and leaves of M. oleifera

The Ca content in the *M. oleifera* leaves from the three regions was 2170.89±11.27 mg/100 g, 21200.99±18.77 mg/100 g and 21100.27±13.72 mg/100 g in Kilimanjaro, Dodoma and Iringa respectively. The mean of Ca in the leaves from all three regions was 21400.06 ± 14.68 mg/100 g. However, no significant difference was observed in the Ca content in *M. oleifera* leaves from the three regions ($F_{2,\ 29}$ = 0.362, p = 0.70). In the seeds samples, the results showed that the mean Ca contents were 9800.72 ± 0.41 mg/100 g, 9900.23 ± 6.84 mg/100 g and 11400.50 ± 5.28 mg/100 g for Kilimanjaro, Dodoma and Iringa, respectively. Also, a significant difference was observed in the Ca contents from the three studied regions ($F_{2,\ 29}$ = 9.177, p = 0.002). The difference might be attributed to the environment where it is grown. The level of Ca observed is within the range of ones reported by Jongrungruangchok *et al.*, 2010 that the Ca content of the *M. oleifera* leaves ranged from 15100 to 29510 mg/kg, which are comparable to those recorded in this study. The level of Ca obtained for the leaf of Moringa is about four times that in milk and six times that observed in *Amaranthus* sp. (Sharma *et al.*, 2012); hence as a complement in human diet, it is likely to meet the daily requirement.

Variation of Pothassium (K) in seed and leaves of M. oleifera

The average K concentration in the leaves in the three regions was 2370.75 ± 204.06 mg/100 g. The results showed that the K contents for the leaves in three regions were 2350.480± 0.83 mg/100 g, 2356.50±115.8 mg/100 g and 2423.66±426.56 mg/100 g in Kilimanjaro, Dodoma and Iringa, respectively. The results are similar to the one reported by Yaméogo *et al.* (2011) who reported K levels of Moringa leaf range from 3086 to 22500 mg/100g. No significant difference was observed in the three studied regions (F_2, 29 =0.532, p = 0.594). The K content in seed samples from the three regions was 1139.29±2.85 mg/100 g, 2356.50 ± 115.8 mg/100 g and 2423.66±426.56 mg/100 g in Kilimanjaro, Dodoma and Iringa respectively. No significant difference was observed in K content for the seed samples in the three studied regions (F_2, 29 = 9.156, p = 0.857). Potassium (K) is important in the proper function of the brain as well as nerves, thereby preventing stroke.

Variation of Sodium (Na) in seed and leaves of M. oleifera

The results showed that the Na content in the leaves was 36.88±2.99 mg/100 g, 1.75±0 .41 mg/100 g and 1.83±0.23 mg/100 g in Kilimanjaro, Dodoma and Iringa, respectively. The average Na content in the leaves in all samples was 211.89±29.82 mg/100 g. No significant difference was observed for the Na content in the leaves from the studied regions (F2, 29 =3.739, p = 0.037). The Na content in the seed samples was 2350.480±0.83 mg/100 g, 1043.76±73.65 mg/100 g and 1043.76±73.65 mg/100 g in Kilimanjaro, Dodoma and Iringa, respectively. The mean Na content in the seed samples from the three regions was 1018.55±93.99 mg/100 g. Aslam *et al.* (2005) reported similar range 1032 to 2105 mg/kg in the seeds. However, no significant difference was observed in the Na content for the seed samples in the three studied regions ($F_{2,\ 29}$ = 2.86, p = 0.089).

Variation of phosphorus (P) in seed and leaves of M. oleifera

The P concentrations in leaves were 36.88± 2.99 mg/100 g, 34.38 ± 3.15 mg/100 g and 34.38 ± 3.15 mg/100 g in Kilimanjaro, Dodoma and Iringa regions, respectively. The total means the P concentration of leaves from the three regions was 35.49 ± 3.00. However, no significant difference was observed in the leaf samples from the three regions ($F_{2,\ 29}$ = 0.206, p = 0.815). The concentration of P in the seeds was 11.19±0.17 mg/100 g, 15.13±1.54 mg/100 g and 15.13±1.54 mg/100 g in Kilimanjaro, Dodoma and Iringa, respectively. A significant difference was observed for the concentration of P in seed samples from the three regions ($F_{2,\ 29}$ = 12.153, p = 0.001).

Variation of beta-carotene *in seed and leaves of M. oleifera*

The average concentrations of *Beta*-carotene in the leaf samples for the three regions were: 32.23±3.09 mg/100 g, 34.84±4.81 mg/100 g, and 32.88±2.34 mg/100 g in Kilimanjaro, Dodoma and Iringa, respectively. No significant difference was observed for β-carotene in leaf samples obtained in three regions ($F_{2,\ 29}$ = 1.440, p = 0.255). The mean concentration of *Beta*-carotene in the leaf samples obtained from the three regions was 33.32 ± 3.63 mg/100 g. The concentration of *beta*-carotene in seed samples obtained from three regions was 2.72±0.16

mg/100 g, 2.743±0.65 mg/100 g and 5.38±0 .82 mg/100 g respectively. The mean concentration of β-carotene in seeds was 3.33±1.29 mg/100 g. There was a significant difference in P in seed samples obtained from the three regions ($F_{2, 29} = 24.522$, $p < 0.0001$).

Conclusion

The present study found a significant nutritional composition in leaves and seeds of *M. oleifera* from the all three District in Tanzania under investigation. The leaves and seed macro and micronutrient composition analysis found in *M. oleifera* showed significant concentrations in nutrient concentrations. Significant differences were observed regarding the nutritional composition in the leaves and the seeds of *M. oleifera*, but no significant differences were observed in nutrition contents in seeds and leaves in the three regions. It is important to include *M. oleifera* in foods and feed to improve animal and human nutrition.

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