*Article*

# Diversity in the Nutritional Attributes of Some *Moringa oleifera* Lam. Cultivars from Different Geographical Origins

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**Abstract:** This study aimed to assess the variations in the nutritional attributes of thirteen *Moringa oleifera* cultivars. Leaves from six-month-old plants were harvested and tested for various nutritional attributes. There were significant ($p \leq 0.05$) differences in the carbohydrates, energy, some of the sugars and fibre amongst the cultivars. The levels of moisture in the cultivars ranged from 7.10% to 8.20%. Additionally, there were significant ($p \leq 0.05$) differences across the cultivars in microelements studied except for zinc (Zn). These data revealed that plants from different geographical provenances differed in their adapting to varied environments. In general, under the same cultivation, management and environmental conditions, the main reasons for these differences occurred in cultivars could be associated with the genetic background of each *M. oleifera* germplasm. However, the study cautions on the differences of nutritional properties, as some of the cultivars have been reported not to be pharmacological potent.

**Keywords:** Antioxidants; Flavonoids; Moringa; Provitamin A; Total Phenolics

## 1. Introduction

*Moringa oleifera* Lam. is listed in the top 10% out of 500,000 plant species gaining popularity due to its broad spectrum of both nutritional and phytochemical profiles [1,2]. *Moringa oleifera* is the most utilised and cultivated species of the Moringaceae family (order Brassicales) because of its ability to grow in a wide range of conditions and the medico-nutritional properties [3]. Due to its widespread applications, many countries in Africa, South America, and Asia have intensified cultivation programmes [4]. In Africa, for example, hope has been placed on the use of *M. oleifera* in alleviating malnutrition, unemployment and has been coined to change the lives of many [5]. In South Africa, the cultivated plant is processed into different products, including powder, capsules and tea bags used as either self-care products for lifestyle conditions or general nutritional supplements. Several *M. oleifera* cultivars and germplasms suitable for several desirable traits like leaf yield, seed production, medicinal properties, and nutritional levels have been produced throughout the world. Results from previous research indicated that these cultivars differ in many traits for example Zheng et al. [4] reported differences in adaptability of eight cultivars in mainland China while Ndhlala et al. [6] reported variation in antioxidant, antimicrobial properties and phytochemical composition. This study aimed to assess the variations in the nutritional attributes of thirteen *M. oleifera* cultivars obtained as seeds from different geographic locations worldwide and cultivated locally to select the most suitable variety for utilisation in programmes designed to improve the nutritional benefits of local *M. oleifera* cultivation.

## 2. Materials and Methods

### 2.1. Experimental site and cultivars used

Thirteen *M. oleifera* Lam. cultivar seeds originating from different geographical locations in the world were cultivated at the Agricultural Research Council (ARC) experimental farm, Roodeplaat, Pretoria (25°36'1.85"S; 28°21'54.78"E). The farm is located at an elevation of 1160 m a.s.l.. The vegetation of the farm location is described as savanna [7], and Acocks [8] describes the area as Sourish Mixed Bushveld. The area receives annual precipitation ranging from 380 mm to 700 mm [9]. The average minimum and maximum temperatures in the summer range are 29°C and 20°C, respectively, while winter temperatures are 16 °C and 2 °C, respectively.

The details of the cultivars planted are presented in Table 1. The trial layout was a randomised block design fashion with all the cultivars receiving the same management practices of no fertilisers, watering and constant weeding.

**Table 1.** Details of the *Moringa oleifera* cultivars used in the study, obtained from different origins.

| Cultivar | Country of Origin | Source of seeds |
|---|---|---|
| Limpopo | South Africa | Local domesticated cultivar from Limpopo Province, South Africa |
| CHM | South Africa | Silver Hill, KwaZulu-Natal Province, South Africa |
| SH | South Africa | Silver Hill, KwaZulu-Natal Province, South Africa |
| TOT4893 | Thailand | World Vegetable Centre (Taiwan) |
| TOT4951 | Thailand | World Vegetable Centre (Taiwan) |
| TOT4977 | Thailand | World Vegetable Centre (Taiwan) |
| TOT 5028 | Thailand | World Vegetable Centre (Taiwan) |
| TOT5077 | Thailand | World Vegetable Centre (Taiwan) |
| TOT5169 | Thailand | World Vegetable Centre (Taiwan) |
| TOT5330 | Thailand | World Vegetable Centre (Taiwan) |
| TOT7266 | Thailand | World Vegetable Centre (Taiwan) |
| TOT4100 | Taiwan | World Vegetable Centre (Taiwan) |
| TOT4880 | USA | World Vegetable Centre (Taiwan) |

### 2.2. Sample Preparation and methods of analysis

Fresh leaf samples from each of the *M. oleifera* cultivars were harvested separately, and nutrients were fully preserved by carefully harvesting the leaflets, which were immediately placed in labelled envelopes, sealed in vessels containing liquid nitrogen for transportation to freeze-drying facility. The harvested samples were freeze-dried for 48 h. and dried plant materials were ground into powder and used for analysis. The standard and referenced methods' concentrations of nutrients were determined [10-13].

### 2.3. Data Analysis

A one-way analysis of variance (ANOVA) was done to determine the difference of properties from various cultivars ($p \leq 0.05$). The least significant differences (LSD) test was used to separate the means. We also determined correlation amongst different measured attributes. Statistical analysis was carried out in the R statistical package version 3.6.3 [14].

## 3. Results and Discussion

The results of the carbohydrates, energy, sugars and fibre are shown in Table 2. There were significant ($p \leq 0.05$) differences in the carbohydrates, energy, some of the sugars and fibre. The local domesticated cultivar from Limpopo Province, South Africa, exhibited higher ($p \leq 0.05$) total sugars, energy, glycaemic carbohydrates, and glucose than the other cultivars. Cultivars TOT4977 and TOT5028 from Thailand showed lower ($p \leq 0.05$) levels of total sugars, energy, glycaemic carbohydrates and sucrose. There were, however, no significant differences ($p \geq 0.05$) in the levels of glucose, lactose and maltose detected in all the tested cultivars. In all the cultivars, very low amounts (< 0.3 g/100g) of lactose and maltose were detected.

**Table 2.** Concentration of various nutrients of *Moringa oleifera* found in different cultivars from several origins.

| Cultivar | Total Sugar | Total energy | Glycemic carbohydrates | Fructose | Glucose | Lactose | Maltose | Sucrose | Total Dietary Fibre |
|---|---|---|---|---|---|---|---|---|---|
| | g/100g | KJ/100g | g/100g | g/100g | g/100g | g/100g | g/100g | g/100g | g/100g |
| CHM | 5.70 ± 0.33cd | 612 ± 0.707d | 6.00 ± 0.27efg | 1.10 ± 0.37ab | 1.30 ± 0.48a | <0.3 | <0.3 | 3.30 ± 0.27c | 43.30 ± 0.03d |
| Limpopo | 7.90 ± 0.45ab | 741 ± 4.240a | 8.00 ± 0.35a | 1.00 ± 0.33b | 1.50 ± 0.55a | <0.3 | <0.3 | 5.40 ± 0.44b | 40.80 ± 0.02h |
| SH | 5.70 ± 0.33cd | 666 ± 3.540bc | 7.50 ± 0.34b | 1.30 ± 0.42a | 1.40 ± 0.51a | <0.3 | <0.3 | 3.00 ± 0.01cd | 42.70 ± 0.08f |
| TOT4100 | 4.90 ± 0.28e | 588 ± 0.707e | 5.00 ± 0.23hi | 1.30 ± 0.42a | 1.10 ± 0.40a | <0.3 | <0.3 | 2.50 ± 0.21cde | 45.80 ± 0.03a |
| TOT4880 | 4.80 ± 0.27e | 616 ± 4.240f | 5.30 ± 0.24gh | 0.70 ± 0.23b | 0.60 ± 0.21a | <0.3 | <0.3 | 3.50 ± 0.28c | 44.80 ± 0.04c |
| TOT4893 | 4.70 ± 0.27e | 555 ± 7.07d | 5.10 ± 0.23hi | 0.70 ± 0.23b | 1.00 ± 0.40a | <0.3 | <0.3 | 3.00 ± 0.24cd | 43.30 ± 0.03d |
| TOT4951 | 6.70 ± 0.38bc | 670 ± 0.707b | 7.00 ± 0.31cd | 1.10 ± 0.37ab | 1.10 ± 0.40a | <0.3 | <0.3 | 6.00 ± 0.50ab | 41.30 ± 0.02g |
| TOT4977 | 4.70 ± 0.27e | 651 ± 5.660c | 5.00 ± 0.23hi | 0.90 ± 0.30b | 1.10 ± 0.40a | <0.3 | <0.3 | 2.70 ± 0.23cde | 42.90 ± 0.03e |
| TOT5028 | 3.00 ± 0.17f | 526 ± 4.240g | 4.10 ± 0.18ij | 0.40 ± 0.13bc | 0.90 ± 0.32a | <0.3 | <0.3 | 1.70 ± 0.14ef | 45.70 ± 0.03a |
| TOT5077 | 3.00 ± 0.17f | 552 ± 0.707f | 3.00 ± 0.13j | 0.30 ± 0.10c | 1.10 ± 0.39a | <0.3 | <0.3 | 1.50 ± 0.13f | 45.40 ± 0.08b |
| TOT5169 | 5.50 ± 0.31ed | 532 ± 0.707g | 6.30 ± 0.28de | 1.20 ± 0.40ab | 1.40 ± 0.51a | <0.3 | <0.3 | 2.90 ± 0.24cd | 45.80 ± 0.05a |
| TOT5330 | 5.90 ± 0.34cd | 658 ± 3.540bc | 6.00 ± 0.27efg | 1.30 ± 0.42a | 1.60 ± 0.58a | <0.3 | <0.3 | 3.00 ± 0.24cd | 40.80 ± 0.02h |
| TOT7266 | 5.90 ± 0.34cd | 589 ± 2.830e | 6.00 ± 0.27efg | 1.00 ± 0.33b | 1.30 ± 0.48a | <0.3 | <0.3 | 3.60 ± 0.30c | 42.70 ± 0.03f |

Means with the different superscripts are significantly different ($p \leq 0.05$).

The Taiwanese cultivar TOT4100 (45.8 g/100g) and Thai cultivars TOT5028 (45.7 g/100g), TOT5169 (45.8 g/100g) had significantly ($p \leq 0.05$) higher fibre composition compared to the rest of the tested cultivars while the cultivars from Limpopo and TOT5330 from Thailand had the least (40.8 g/100g for both). Higher fibre composition in the leaflet powders contributes significantly to the pharmacological attributes of the plant as it enhances normal bowel function and subsequently preventing diseases like cancer of the colon [15].

Table 3 represents the results of moisture, ash, fat, cholesterol and protein. There were significant ($p \leq 0.05$) differences across all the cultivars in these parameters except for cholesterol. Higher amounts of moisture, ash, total saturated fat, total monounsaturated fat, and protein were exhibited by TOT4880, TOT5028, TOT4977 and Limpopo cultivars.

The moisture levels in all the cultivars ranged from 7.10% (TOT4951) to 8.20% (TOT4880), which can be considered high. This may be due to the presence of sugars (fructose, glucose, maltose, lactose and sucrose) as presented in Table 2 that results in the MLP being hygroscopic, causing it to absorb moisture from the environment [16]. Higher moisture content in food ingredients reduces shelf-life thus, care needs to be taken when storing the raw powder or some products as in South Africa, *M, oleifera* powder is consumed in many different forms, including capsules.

Higher protein levels in the locally domesticated cultivar from Limpopo Province, South Africa (28.9 g/100g) are encouraging and suggest that the cultivar is a good protein supplement source for population leaving the area and for adoption and cultivation in the other areas considering the fact that the cultivar is already domesticated in South Africa. Protein is one of the key nutrients that is lacking within most of the food products being consumed by the population of South Africa, as mentioned above, primarily replaced by high sugar foodstuffs, alcohol and drinks. The Thai cultivar, TOT5169 exhibited the least protein content (20.8 g/100g).

**Table 3.** Moisture, ash, fat, cholesterol and protein content of some cultivars of *M. oleifera* from different geographic origins.

| Cultivar | Moisture | Ash | Total Saturated Fat | Total Monounsaturated Fat | Total Polyunsaturated Fat | Cholesterol | Protein |
|---|---|---|---|---|---|---|---|
| | % | g/100g | g/100g | g/100g | g/100g | mg/100g | g/100g |
| CHM | $7.50 \pm 0.01^{e}$ | $15.80 \pm 0.06^{d}$ | $0.81 \pm 0.04^{ef}$ | $0.12 \pm 0.06^{c}$ | $1.22 \pm 0.02^{d}$ | <0.9 | $24.4 \pm 0.04^{f}$ |
| Limpopo | $6.90 \pm 0.04^{l}$ | $12.30 \pm 0.04^{h}$ | $1.20 \pm 0.03^{a}$ | $0.16 \pm 0.07^{c}$ | $1.56 \pm 0.02^{a}$ | <0.9 | $28.9 \pm 0.06^{a}$ |
| SH | $7.00 \pm 0.04^{g}$ | $13.70 \pm 0.04^{g}$ | $0.98 \pm 0.08^{bc}$ | $1.08 \pm 0.06^{ab}$ | $0.28 \pm 0.01^{c}$ | <0.9 | $27.8 \pm 0.06^{b}$ |
| TOT4100 | $7.40 \pm 0.02^{f}$ | $15.10 \pm 0.05^{e}$ | $1.04 \pm 0.02^{b}$ | $0.12 \pm 0.06^{c}$ | $1.20 \pm 0.02^{c}$ | <0.9 | $23.6 \pm 0.02^{g}$ |
| TOT4880 | $8.20 \pm 0.01^{a}$ | $16.90 \pm 0.06^{c}$ | $1.00 \pm 0.03^{bc}$ | $1.00 \pm 0.05^{ab}$ | $0.32 \pm 0.01^{c}$ | <0.9 | $23.2 \pm 0.04^{h}$ |
| TOT4893 | $7.30 \pm 0.04^{g}$ | $15.60 \pm 0.07^{d}$ | $0.94 \pm 0.03^{bcd}$ | $0.18 \pm 0.06^{c}$ | $1.22 \pm 0.02^{c}$ | <0.9 | $25.7 \pm 0.04^{d}$ |
| TOT4951 | $7.10 \pm 0.01^{h}$ | $15.00 \pm 0.05^{ef}$ | $0.94 \pm 0.02^{bcd}$ | $0.11 \pm 0.03^{c}$ | $1.34 \pm 0.02^{c}$ | <0.9 | $25.8 \pm 0.05^{cd}$ |
| TOT4977 | $7.40 \pm 0.04^{f}$ | $14.80 \pm 0.05^{f}$ | $1.17 \pm 0.04^{a}$ | $1.20 \pm 0.03^{a}$ | $0.38 \pm 0.01^{b}$ | <0.9 | $25.2 \pm 0.04^{e}$ |
| TOT5028 | $7.60 \pm 0.03^{d}$ | $18.20 \pm 0.07^{a}$ | $0.94 \pm 0.02^{bcd}$ | $0.92 \pm 0.05^{b}$ | $0.30 \pm 0.01^{d}$ | <0.9 | $22.4 \pm 0.02^{i}$ |
| TOT5077 | $7.80 \pm 0.01^{c}$ | $16.90 \pm 0.06^{c}$ | $0.93 \pm 0.01^{cd}$ | $0.91 \pm 0.06^{b}$ | $0.32 \pm 0.01^{d}$ | <0.9 | $23.2 \pm 0.02^{h}$ |
| TOT5169 | $8.10 \pm 0.04^{b}$ | $17.50 \pm 0.06^{b}$ | $0.99 \pm 0.02^{bc}$ | $0.92 \pm 0.06^{b}$ | $0.32 \pm 0.01^{c}$ | <0.9 | $20.8 \pm 0.04^{k}$ |
| TOT5330 | $7.50 \pm 0.01^{e}$ | $15.80 \pm 0.05^{d}$ | $0.94 \pm 0.03^{bcd}$ | $0.16 \pm 0.05^{c}$ | $1.23 \pm 0.02^{c}$ | <0.9 | $25.8 \pm 0.06^{cd}$ |
| TOT7266 | $7.50 \pm 0.04^{e}$ | $17.50 \pm 0.06^{b}$ | $0.75 \pm 0.01^{f}$ | $0.13 \pm 0.04^{c}$ | $1.03 \pm 0.02^{e}$ | <0.9 | $21.6 \pm 0.03^{j}$ |

Means with the different superscripts are significantly different ($p \leq 0.05$).

Table 4 presents the microelement levels of the different *M. oleifera* cultivars. There were significant ($p \leq 0.05$) differences across all the cultivars in microelements studied except for zinc (Zn).

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Cultivar TOT5028 from Thailand contained the highest calcium levels (51893 mg/100g), while the domesticated Limpopo cultivar contained the least (31363 mg/100g). For Iron (Fe) and potassium (K), cultivar TOT5077 and SH exhibited the highest amounts of Fe and K, respectively, while cultivar TOT7266 and TOT5028 recorded the least levels, respectively. Microelements such as Ca, Fe, K and Zn are essential physiologically in the human body to maintain total body health [17]. For example, like Ca, microelements are required daily to promote bone growth and formation in infants and the normal development of fetal bones. Some of the foodstuffs that naturally contain calcium include green leafy vegetables, including *M. oleifera,* as presented in Table 4.

**Table 4.** Micro elements content of some cultivars of *M. oleifera* from different geographic origins.

| Cultivar | calcium | Cadmium | Iron | Lead | Magnesium | Mercury | Sodium | Potassium | Phosphorus | Zinc |
|---|---|---|---|---|---|---|---|---|---|---|
| | mg/1000g | mg/1000g | mg/1000g | mg/1000g | mg/1000g | mg/1000g | mg/1000g | mg/1000g | mg/1000g | mg/1000g |
| CHM | 40654 ± 116$^{d}$ | <0.01 | 382 ± 0.679$^{b}$ | <0.04 | 4722 ± 9.7$^{j}$ | <0.01 | 14.7 ± 0.01$^{f}$ | 11550 ± 0.891$^{b}$ | 3397 ± 6.97$^{i}$ | 22.9 ± 4.47$^{a}$ |
| Limpopo | 31363 ± 90$^{h}$ | <0.01 | 243 ± 0.438$^{k}$ | <0.04 | 4549 ± 9.3$^{k}$ | <0.01 | 9.1 ± 0.01$^{k}$ | 10390 ± 0.368$^{d}$ | 3808 ± 7.81$^{d}$ | 26.5 ± 5.18$^{a}$ |
| SH | 32652 ± 93$^{g}$ | <0.01 | 346 ± 0.622$^{g}$ | <0.04 | 3460 ± 7.1$^{l}$ | <0.01 | 29 ± 0.04$^{c}$ | 11916 ± 0.523$^{a}$ | 2620 ± 5.37$^{m}$ | 17.5 ± 3.42$^{a}$ |
| TOT4100 | 40161 ± 115$^{e}$ | <0.01 | 181 ± 0.325$^{e}$ | <0.04 | 4901 ± 10.1$^{i}$ | <0.01 | 16.8 ± 0.03$^{d}$ | 8839 ± 0.679$^{f}$ | 3308 ± 6.79$^{j}$ | 20.5 ± 4.00$^{a}$ |
| TOT4880 | 48150 ± 138$^{c}$ | <0.01 | 290 ± 0.523$^{i}$ | <0.04 | 7998 ± 16.4$^{b}$ | <0.01 | 9 ± 0.01$^{k}$ | 5742 ± 0.438$^{k}$ | 3969 ± 8.13$^{c}$ | 23.5 ± 4.58$^{a}$ |
| TOT4893 | 37785 ± 108$^{d}$ | <0.01 | 424 ± 0.750$^{f}$ | <0.04 | 5337 ± 10.9$^{g}$ | <0.01 | 11.8 ± 0.01$^{h}$ | 8438 ± 0.622$^{g}$ | 4863 ± 9.97$^{a}$ | 22.1 ± 4.31$^{a}$ |
| TOT4951 | 41871 ± 120$^{ef}$ | <0.01 | 234 ± 0.410$^{l}$ | <0.04 | 7354 ± 15.1$^{c}$ | <0.01 | 3.1 ± 0$^{l}$ | 6225 ± 0.325$^{j}$ | 4712 ± 9.66$^{b}$ | 27.0 ± 5.28$^{a}$ |
| TOT4977 | 42320 ± 121$^{f}$ | <0.01 | 405 ± 0.721$^{h}$ | <0.04 | 7133 ± 14.6$^{d}$ | <0.01 | 9.8 ± 0.01$^{j}$ | 8047 ± 0.523$^{h}$ | 3732 ± 7.65$^{e}$ | 22.2 ± 4.33$^{a}$ |
| TOT5028 | 51893 ± 148$^{a}$ | <0.01 | 244 ± 0.438$^{c}$ | <0.04 | 5568 ± 11.4$^{f}$ | <0.01 | 30.6 ± 0.04$^{b}$ | 2387 ± 0.750$^{m}$ | 3695 ± 7.58$^{f}$ | 24.7 ± 4.82$^{a}$ |
| TOT5077 | 47814 ± 137$^{c}$ | <0.01 | 512 ± 0.919$^{j}$ | <0.04 | 6749 ± 13.8$^{e}$ | <0.01 | 16.2 ± 0.01$^{e}$ | 6410 ± 0.410$^{i}$ | 3048 ± 6.25$^{k}$ | 23.0 ± 4.48$^{a}$ |
| TOT5169 | 53008 ± 151$^{b}$ | <0.01 | 496 ± 0.891$^{d}$ | <0.04 | 8108 ± 16.6$^{a}$ | <0.01 | 13.5 ± 0.01$^{g}$ | 11416 ± 0.721$^{c}$ | 3678 ± 7.54$^{g}$ | 22.4 ± 4.37$^{a}$ |
| TOT5330 | 42615 ± 122$^{d}$ | <0.01 | 203 ± 0.368$^{i}$ | <0.04 | 5553 ± 11.4$^{f}$ | <0.01 | 10.3 ± 0.01$^{i}$ | 9508 ± 0.438$^{e}$ | 3636 ± 7.45$^{h}$ | 22.0 ± 4.30$^{a}$ |
| TOT7266 | 42473 ± 121$^{b}$ | <0.01 | 292 ± 0.523$^{a}$ | <0.04 | 5160 ± 10.6$^{h}$ | <0.01 | 80.1 ± 0.09$^{a}$ | 3000 ± 0.919$^{l}$ | 2684 ± 5.50$^{l}$ | 18.7 ± 3. 65$^{a}$ |

Means with the different superscripts are significantly different ($p \leq 0.05$).

Table 5 indicates the variation of vitamins exhibited by the thirteen *M. oleifera* cultivars. TOT5169 had the greatest ($p \leq 0.05$) amounts of folic acid (vitamin B) and vitamin A. While, TOT5077 and Limpopo cultivar had the highest ($p \leq 0.05$) amounts of vitamin C. However, vitamin B12 was not detected in any of the cultivars. Vitamin A includes retinol, retinal and retinoic acids; these are responsible for various physiological processes such as improving eye vision, skin development, boosting the immune system and embryonic growth. *M. oleifera* is reported to contain more Vitamin A than in carrots [18]. Folates are B-vitamins responsible for DNA synthesis and cell division. Lack of folates in the diet may lead to neural tube defects in the brain and spinal cords of babies, therefore folate containing diet or supplements is highly recommended during pregnancy. Vitamin C, also known as Ascorbic acid, is found in high amounts of about 200 mg/100 g, greater than in orange fruits [19]. Vitamin C is responsible for lowering blood cholesterol levels and is also involved in the absorption of iron. Vitamin C is also known to act as an antioxidant. These antioxidants are responsible for acting against free radicals, the reactive oxygen species (ROS).

**Table 5.** Vitamin composition of some cultivars of *M. oleifera* from different geographic origins.

| Cultivar | Folic acid | Vitamin A | Vitamin B12 | Vitamin C |
|---|---|---|---|---|
| | mg/100g | μg/100g | μg/100g | mg/100g |
| CHM | $0.94 \pm 0.01^{d}$ | $527 \pm 3.79^{d}$ | Not Detected | $275.5 \pm 0.265^{e}$ |
| Limpopo | $1.07 \pm 0.01^{f}$ | $279 \pm 2.09^{ef}$ | Not Detected | $364.9 \pm 0.341^{i}$ |
| SH | $1.12 \pm 0.02^{f}$ | $978 \pm 3.06^{f}$ | Not Detected | $276.3 \pm 0.473^{e}$ |
| TOT4100 | $0.09 \pm 0.02^{a}$ | $730 \pm 2.00^{a}$ | Not Detected | $283.2 \pm 1.740^{g}$ |
| TOT4880 | $1.05 \pm 0.02^{e}$ | $2277 \pm 2.00^{e}$ | Not Detected | $280.1 \pm 0.252^{f}$ |
| TOT4893 | $0.35 \pm 0.03^{c}$ | $758 \pm 2.00^{c}$ | Not Detected | $263.4 \pm 0.510^{d}$ |
| TOT4951 | $0.08 \pm 0.02^{a}$ | $832 \pm 2.00^{a}$ | Not Detected | $246.9 \pm 0.404^{ab}$ |
| TOT4977 | $1.09 \pm 0.01^{f}$ | $956 \pm 2.69^{f}$ | Not Detected | $256.8 \pm 1.770^{c}$ |
| TOT5028 | $0.16 \pm 0.02^{b}$ | $642 \pm 1.43^{b}$ | Not Detected | $382.3 \pm 0.511^{j}$ |
| TOT5077 | $1.07 \pm 0.02^{f}$ | $279 \pm 2.31^{ef}$ | Not Detected | $364.9 \pm 2.070^{i}$ |
| TOT5169 | $1.64 \pm 0.03^{g}$ | $790 \pm 2.68^{g}$ | Not Detected | $306.8 \pm 0.503^{h}$ |
| TOT5330 | $1.10 \pm 0.02^{f}$ | $341 \pm 1.33^{f}$ | Not Detected | $248.2 \pm 0.306^{b}$ |
| TOT7266 | $0.22 \pm 0.02^{b}$ | $815 \pm 1.00^{b}$ | Not Detected | $244.4 \pm 0.436^{a}$ |

Means with the different superscripts are significantly different ($p \leq 0.05$)

Figure 1 indicates the correlogram of various nutrients, minerals and fats found in *M. oleifera*. There was mostly no correlation between the different measured attributes, except for a few. Total sugar and sucrose; glucose and fructose; moisture and glycemic carbohydrates; phosphorus and calcium; phosphorus and magnesium; calcium and ash; total fat and saturated fat; magnesium and ash; magnesium and calcium. While there were significant negative relationships between the following pairs: calcium and total sugar; calcium and sucrose; ash and total sugar; ash and sucrose; magnesium and total sugar; total polyunsaturated fats and total monosaturated fats. These significant relationships indicate the potential of using models to predict some of these nutrients, fats and minerals. This would significantly reduce the expense used in wet chemical analysis for measuring these attributes.

South Africa does not only suffer from the prevalence of infectious diseases associated with underdevelopment, poverty and under-nutrition but there is also an emerging epidemic of chronic diseases linked to over-nutrition and Western types of diet and lifestyle [20]. An example is that in South Africa, nearly 30% of dietary energy is supplied by sugar, fat and alcohol, which have a high energy density but are very low in other nutrient densities. Rapid urbanisation, rising incomes and poor dietary choices have acted as drivers for this emerging epidemic of chronic lifestyle diseases. The net result is an increased burden on the national healthcare system because of the effects of the two forms of malnutrition which are undernutrition and over-nutrition.

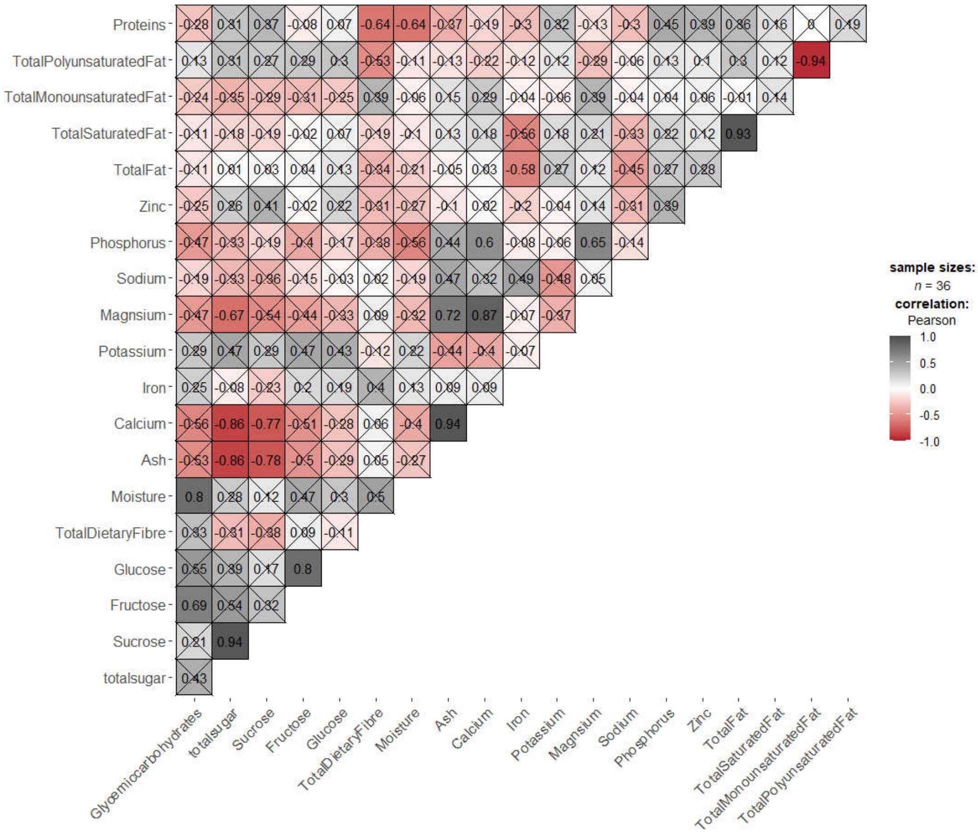


**Figure 1.** Correlogram indicating the relationship between various nutrients found in different *Moringa oleifera* variants. X indicates a non-significant correlation at $p < 0.05$.

The high nutritional content of *M. oleifera* leaflets makes the plant an extraordinarily attractive tool for addressing malnutrition throughout the developing world, including South Africa. The selection of cultivars with advantages of high nutritional content or any other factor is critical in malnutrition alleviation programmes. For example, in South Africa, The National Government, through the Department of Science and Innovation, Directorate of Indigenous Knowledge-based Technology Innovation, initiated a Moringa Flagship made up of several communities that are encouraged to grow *M. oleifera* for food and nutritional security. These communities are linked to researchers from universities and science councils to assist them with cultivation and quality control and product formulations. Therefore, it is critical to understand variants within *M. oleifera* cultivars to select those that simultaneously have high nutritional content for better nutraceutical effect and high medicinal properties.

## 4. Conclusions

These data revealed that plants from different geographical provenances differed in their adapting to varied environments and suggested severe differences, which may be one of the factors affecting the quality of nutrients, phytochemical, leaf and seed yield of *M. oleifera*. In general, under the same cultivation, management and natural environmental conditions, the main reasons for these differences occurred in cultivars could be associated with the genetic background of each *M. oleifera* germplasm. Additionally, Makita et al. [21] reported that not all *M. oleifera* contain an important flavonoid, rutinoside, responsible for the plant's nutritional and therapeutic propreties. Taking note of the presence of these secondary metabolites will greatly improve the identification of nutritional and pharmacological potent cultivars.

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