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Determination of proximate and mineral compositions of *Moringa oleifera* and *Moringa stenopetala* leaves cultivated in Arbaminch Zuria and Konso, Ethiopia

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This study presents the proximate and mineral composition analysis of *Moringa oleifera* and *Moringa stenopetala* leaves collected from two different agro-ecological zones namely Arbaminch Zuria and Konso in Southern Nation Nationalities and Peoples Region (SNNPR), Ethiopia. *M. oleifera* and *M. stenopetala* leaves were collected using random sampling method from four sampling sites namely Secha, Karat, Sikela, Gato. Before the samples were analyzed, parameters such as temperature, volume of reagents and time until complete digestion were systematically optimized. Analysis of variance was used to compare the proximate and elemental composition of leaf samples as well as mineral composition of soil. The results of this study revealed that, *M. oleifera* leaf samples from the Secha and Karat sampling sub-sites have shown the average moisture, ash, crude fiber, crude lipid and protein contents of 6.88 ± 0.82 , 15.3 ± 1.02 , 5.51 ± 0.08 , 7.11 ± 0.52 , $24.8 \pm 1.80\%$ and 6.60 ± 0.79 , 15.6 ± 1.11 , 6.13 ± 0.22 , 7.35 ± 0.48 , $24.3 \pm 1.73\%$, respectively. The average moisture, ash, crude fiber, crude lipid and protein contents of 7.92 ± 0.85 , 14.9 ± 0.93 , 5.03 ± 0.12 , 3.65 ± 0.11 , $27.3 \pm 2.10\%$ and 7.73 ± 0.96 , 14.1 ± 0.87 , 5.87 ± 0.21 , 4.29 ± 0.12 , $30.2 \pm 2.61\%$ were determined for *M. stenopetala* leaf samples from the Sikela and Gato, respectively. The contents of the nutrients found in Moringa leaves have shown no significant differences from the two agro-ecological zones except some nutrients (ash, lipid, and protein). The K, Na, Mg, Ca, Mn, Zn, Fe, and Cu concentration determined from Moringa leaf samples from the two agro-ecological zones was ranged between 9570-14047, 1287-1298, 4273-4550, 18230-19026, 72.4-87.5, 21.3-57.6, 80.1-82.3 and 3.43-5.10 mg/Kg, respectively. The comparison of mean values of macro and micro nutrient of Moringa leaves and soils showed no significant difference between the two agro-ecological zones except some metals such as K, Zn and Cu. The present analysis revealed that Moringa leaves contained considerable amount of nutrients and hence used as food supplement for the community.

Key words: Nutritional compositions, elemental composition, Moringa species, agro-ecological zones, proximate analysis.

INTRODUCTION

In Africa, many studies have indicated that a vast number of indigenous wild plants play a significant role in the diet of the population (Muhammad et al., 2011). Vegetables

are the cheapest and the most available sources of important nutrients, supplying the body with minerals, salts, vitamins and certain hormone precursors, protein,

energy and essential amino acids (Amaechi, 2009).

M. oleifera and *M. stenopetala* are the two most common species among the 13 species of the Moringa family. *M. oleifera* originates from the Himalaya and *M. stenopetala* is endemic to East Africa (Bosch, 2004). All parts of the tree except the wood are edible, providing a highly nutritious food for both humans and animals. *M. stenopetala* is one of the most frequently cultivated indigenous species for its palatable leaves in the semiarid areas of Konso, Derashe and Arbaminch Zuria districts of the Southern Rift Valley of Ethiopia and locally called as "Haleko" or "Shiferaw". It is also cultivated from the lower Omo Valley to the North and in the neighboring regions of South Omo, Gamo-Gofa and Borena (Grubben and Denton, 2004).

Moringa is a multi-purpose miracle tree with tremendous potential uses such as food for human beings, feed for livestock, dye, perfume, skin lotion, lubricant and water purification (Agena, 2009). The Moringa leaves are nutritionally rich and an excellent source of concentrated proteins, vitamins and minerals (Armelle and Melanie, 2010). It has also potential medicinal uses such as: the root bark is being used to kill different kinds of intestinal worms, increases food appetite, protect abdominal constipation, cure for different kinds of respiratory diseases such as bronchitis and influenza and the stem bark is being used to treat eye diseases, intestinal worms, and to decrease or neutralize the venom power of snake, bee and scorpion (Grubben and Denton, 2004).

A recent study conducted by Melesse et al. (2009) indicated that the leaves of *Moringa stenopetala* are rich in protein (28.2%) and contain reasonable amounts of essential amino acids of which some are comparable with those found in soybean meal. It is a multipurpose tree that is cultivated both for human food and animal feed in Southern Ethiopia. Moringa leaves have been consumed by Asian people for millennia as a healthy food product. Studies from other countries indicate that the leaves have immense nutritional value such as phytochemicals, vitamins, minerals, and amino acids (Busani et al., 2011). As such, the leaves have been used to combat malnutrition, especially among infants and nursing mothers. The Romans, Greeks, and Egyptians extracted edible oil from the seeds and used it for perfume and as a skin lotion. People in the Indian subcontinent have long used Moringa pods for food. The edible leaves are eaten throughout East Africa and parts of Asia. Moringa leaves are edible and are of high nutritive value (Tetteh, 2008). It has been reported that *M. oleifera* leaves product, especially leaf powder, is becoming increasingly popular in Ethiopia because of its outstanding indigenous nutritive and medicinal value. The leaves are also free of anti-

nutritive factors such as phenols, tannins, and saponins (Ijarotimi et al., 2013).

In many developing countries, the supply of minerals is inadequate to meet the mineral requirements of farm animals and rapidly growing population. Mineral composition of a plant plays significant role its nutritional, medicinal and therapeutic values (Al-Kharusi et al., 2009).

M. oleifera contains several elements which are the basic building block of matter. Some of the elements are calcium, magnesium, potassium, sodium and the minor elements are iron, zinc, copper and manganese (Melesse and Berihun, 2013). However, complete information on the nutritional compositions of main edible parts of both Moringa species, that is, leaves cultivated in different agro-ecological zones of southern Ethiopia is still scarce. Therefore, the objectives of this study are: (1) to investigate the effect of agro-ecological variations in nutritional levels of leaves in Moringa species (2) to assess the nutritional levels of leaves in the two Moringa species in comparison with similar studies (3) to compare the proximate compositions in the leaves powder of *M. oleifera* and *M. stenopetala* grown in two different agro-ecological zones (4) to optimize the sample digestion method for both leaf and soil samples; and (5) to investigate and compare the elemental compositions of leaves powder of *M. oleifera* and *M. stenopetala* and the supporting soils in two different agro-ecologic zones..

MATERIALS AND METHODS

Description of the study area

The study was conducted in Arbaminch Zuria and Konso districts of SNNPR, Ethiopia. Arbaminch Zuria district is located at 6° 01'59" N and 37° 32'59" E, altitude of 1269 m.a.s.l and 505 km away from the capital city, Addis Ababa. Konso district is located at 5°15'00" N and 37°28'59" E and altitude of 1031 m.a.s.l. It is 536 Km far from Addis Ababa. Four sampling sub-sites (that is, two from each district) were selected, namely Secha and Sikela from Arbaminch Zuria and Karat and Gato from Konso district.

Chemicals and reagents

All chemicals and reagents were of analytical reagent grade and obtained from Ambo University Chemistry Laboratory. Acid washed glassware and deionized water were used throughout the analysis.

Sampling protocol

Leaf samples

Samples of fresh Moringa leaves were collected from matured *M. oleifera* from Secha and Karat and *M. stenopetala* from Sikela and

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Gato sub-sites. Each sample was collected randomly from ten trees in each sampling sub-sites. About 500 g of the samples were collected from each agro-ecological zone and was placed in polyethylene plastic bags, labeled and transported to the laboratory for further treatment.

Soil samples

Soil samples were collected from the surface soil layers with a depth of about 0 to 15 cm at the point where Moringa leaves plugged. About 500 g of soil samples were collected from each sub-site into polyethylene plastic bags, labeled and transported to the laboratory for further treatment.

Sample preparation

Leaf samples

The leaves were washed with deionized water to remove dust materials and air dried in shade for two weeks to ensure their greenish coloration and maintain nutritional values. The dried leaves were milled and sieved with 0.5 mm sieve. The powders were packaged into polyethylene bags, labeled and stored at room temperature ($24 \pm 3^\circ\text{C}$) prior to analysis.

Soil samples

The samples were air dried to constant weight for two weeks, grinded using mortar and pestle, sieved through a 0.5 mm stainless steel sieve and labeled. Finally, 0.5 g aliquot was taken from each sample for digestion.

Proximate composition analysis

Moisture content, total ash content, crude lipid content, and crude protein content were determined using AOAC methods as determined from (AOAC, 1990) and (AOAC, 2000) using AOAC 900.02A and AOAC 978.04 methods.

Moisture content

Moisture content was determined on dry basis. From each site, 2 g of Moringa leaf samples were weighed in triplicates and placed in an oven (Tianjin Taisite instrument, 101-0, China) at 105°C for 3 h. The samples were removed and cooled in desiccators. Then the dried samples were reweighed. The percentage moisture was calculated as follows:

$$\text{Moisture content percentage (\%)} = \frac{(W_1 - W_2)}{W_1} \times 100 \quad 1$$

W_1 = Weight of air dried leaves; W_2 = weight of oven dried leaves.

Total ash content

Total ash content was determined using AOAC 900.02A method as described in (AOAC, 1990). About 2.0 g of leaf samples from each site were weighed in triplicates. Dried and powdered samples were incinerated in a muffle furnace at 550°C for 4 h, cooled in desiccators and weighed until the weight is constant.

$$\text{Total ash (\%)} = \frac{\text{Weight of ash}}{\text{Initial weight of sample}} \times 100 \quad 2$$

Crude fiber content

After introducing 2.0 g sample into the extraction unit, 150 mL of hot 0.2N H_2SO_4 was added and digested for 30 min. Then, the acid was drained and the sample was washed with hot deionized water for 1 h. The crucible was removed and oven dried overnight at 105°C , cooled, weighed, and heated at 550°C in a muffle furnace overnight and reweighed after cooling. Percentage extracted fiber was calculated as:

$$\text{Crude fiber (\%)} = \frac{\text{Weight of digested sample} - \text{Weight of ashed sample}}{\text{Weight of samples}} \times 100 \quad 3$$

Crude lipids content

The lipid content was determined as the weight change recorded after exhaustively extracting a food substance with a non-polar solvent using Soxhlet method and petroleum ether according to AOAC 945.16 method as described in (AOAC, 1990). The solute was separated from the solvent by evaporation of the solvent leaving the extracted lipid. Weight of the solvent flask with lipid was taken. In the present study, 2.0 g of leaf samples from each site were weighed in triplicates. The Soxhlet apparatus was set-up and the samples were extracted with 200 mL of petroleum ether for 6 h. The solvent free fat in the flux was dried in an oven for an hour at 105°C , cooled in desiccators and reweighed until the weight is constant.

$$\text{Crude lipid (\%)} = \frac{(\text{Weight of extract} + \text{Weight of flux} - \text{Weight of flux})}{\text{Initial weight of sample}} \times 100 \quad 4$$

Crude protein content

Crude protein was determined using AOAC 978.04 method as described in (AOAC, 2000). It is a micro Kjeldahl method. In the present study, about 2.0 g of leaf samples from each site were weighed in triplicates. Then, 10 mL of concentrated H_2SO_4 , a mixture of 2.5 g of CuSO_4 , K_2SO_4 and TiO_2 were added into each sample and digested in a Kjeldahl digestion flask (KDN-20C, China) at 380°C for 6 h until the mixture was clear. The digest was filtered into 500 mL volumetric flask and made up to mark with 100 mL deionized water and connected for distillation. Ammonia was steam distilled for an hour to which had been added 20 mL of 40% NaOH solution. Two hundred milliliters of the distillate was collected in 250 mL conical flask containing 20 mL of 0.2N H_2SO_4 and methyl red indicator.

The ammonia that distilled into the receiving conical flask was reacted with 0.2 N H_2SO_4 and the excess acid in the flask was estimated by back titration against 20 mL of 0.1 N NaOH with color change from red to yellow. A blank distilled was collected in 250 mL conical flask containing 20 mL of 0.2N H_2SO_4 and methyl red indicator. The distillate was titrated against 20 mL of 0.1 N NaOH. Total nitrogen in the sample was calculated using colorimetric methods (Nielson, 2010). Crude protein content was obtained by multiplying the nitrogen content using factor 6.25, that is, $\text{N} \times 6.25$ (James, 1995).

Carbohydrate

The carbohydrate content was determined by difference, that is, addition of all the percentages of moisture, ash, crude lipid, crude protein, and crude fiber was subtracted from 100%. This gave the amount of nitrogen-free extract otherwise known as carbohydrate (Mahan et al., 2016).

Table 1. Proximate compositions of *Moringa oleifera* and *Moringa stenopetala* leaf powder (% Dry weight basis).

Sub-site	Sample type	Moisture (%)	Ash (%)	Crude fiber (%)	Crude lipid (%)	Crude protein (%)
Secha	<i>M. oleifera</i>	6.88±0.82	15.3±1.02	5.51±0.08	7.11±0.52	24.8±1.80
Sikela	<i>M. stenopetala</i>	7.92±0.85	14.9±0.93	5.03±0.12	3.65±0.11	27.3±2.10
Karat	<i>M. oleifera</i>	6.60±0.79	15.6±1.11	6.13±0.22	7.35±0.48	24.3±1.73
Gato	<i>M. stenopetala</i>	7.73±0.96	14.1±0.87	5.87±0.21	4.29±0.12	30.2±2.61

$$\%Carbohydrate = 100 - \left(\frac{\%Moisture + \%Ash + \%Crude\ lipid + \%Crude\ protein + \%Crude\ fiber}{5} \right)$$

solution of each element using flame atomic absorption spectrophotometer (FAAS, Model 210-VGP, USA). The concentrations of Ca and Mg were determined by back titration against $MgCl_2 \cdot 6H_2O$ and $CaCl_2 \cdot 2H_2O$.

Energy value

The sample energy value was estimated (in kcal/g) by multiplying the percentages of crude protein, crude lipid, and carbohydrate with the recommended factors (2.44, 8.37, and 3.57 respectively) as proposed by Martin and Coolidge (1978).

Determination of soil pH

A pH glass electrode (Elmetron® EPSI-1, Poland) was used to determine the soil pH. Soil pH was measured in soil-water slurry. The determination of the soil pH is a three-step procedure: First the soil-water slurry in the ratio 1:5 was prepared. Air dried soil of 10 g was taken in a beaker and 50 mL of water was added. The mixture was stirred with glass rod for 15 min, and allowed to stand for 30 min. Secondly, the pH meter was calibrated with a buffer solutions of pH of 4.0, 7.0 and 9.0. Finally, the electrode was immersed into soil-water slurry and the pH was recorded.

Optimization of sample digestion

Sample digestion was carried out using wet digestion with a reflux condenser for both leaf and soil samples. The reagents used were mixture of nitric acid, perchloric acid and hydrogen peroxide. Before the samples were digested for analysis the parameters such as temperature, volume of reagents and time for complete digestion were carefully optimized. The optimum condition is one that meets: Minimum reagent volume, temperature, and digestion time to produce a clear and colorless digested solution.

Wet digestion method

Approximately 0.5 g of each of sample leaves was weighed in triplicate. Two milliliters of concentrated HNO_3 , 1 mL of concentrated $HClO_4$ and 1 mL of H_2O_2 , added to leaf samples and digested at a temperature of 210°C for 2 h. Similarly for soil samples, 6 mL of concentrated HNO_3 , 1 mL of concentrated $HClO_4$ and 0.5 mL of H_2O_2 were added and digested at a temperature of 230°C for 2.5 h.

Determination of minerals

Flame atomic emission spectrophotometer (FAES, ELICO-CL-378, India) was used for analysis of K and Na. Working standard solutions of Mn, Fe, Zn and Cu were prepared from stock standard solution (1000 ppm) and absorbance was noted from standard

Statistical analysis

Each experimental analysis was done in triplicate. Data obtained from experiments were analyzed by one way ANOVA (Analysis of Variance) using SPSS version 17. Significance was accepted at 0.05 level of probability ($p < 0.05$). The analysis was used to compare the proximate and elemental composition of leaf samples of *Moringa* species as well as mineral composition of soil collected from two different agro-ecological zones.

RESULTS AND DISCUSSION

Proximate composition

M. oleifera leaves powder from Secha and Karat

The proximate compositions of *M. oleifera* and *M. stenopetala* leaves powder are presented in Table 1. As indicated in Table 1, the average moisture content range between 6.88 and 6.60% in *Moringa oleifera* leaves powder. The higher moisture content was recorded for the Secha *M. oleifera* leaf samples (6.88%) and the lower moisture content for Karat (6.60%). There was no significant difference in moisture contents of *Moringa oleifera* leaf samples ($P > 0.05$) from the two agro-ecological zones. The moisture content (6.88%) which was recorded from Secha *M. oleifera* was slightly higher than that of similar researches with moisture content values of 3.21% (Anthonia, 2012). Other studies have reported variable moisture contents ranging between 9.53 and 11.76% which was relatively higher than this study (Ogbe and John, 2011; Busani et al., 2011).

The total ash content ranged between 15.30 and 15.60%. The higher ash content was recorded for the Karat *M. oleifera* leaves powder (15.60%) and the lower ash content for the Secha *M. oleifera* leaves (15.30%). There was no significant difference in ash contents of *M. oleifera* leaf samples ($P > 0.05$) from the two agro-ecological zones. The ash content (15.60%), which was recorded from Karat *M. oleifera* leaves powder, was comparatively higher when compared to values obtained from similar research with ash content values of 7.13 and

10.6%, respectively (Onu and Aniebo, 2011; Busani et al., 2011). Thus, the result indicated that *M. oleifera* leaves collected from the two agro-ecological zones were rich in mineral elements.

Crude fiber of the *M. oleifera* leaves powder ranged from 5.51 to 6.13%. Higher crude fiber (6.13%) was recorded from Karat site and lower 5.51% was recorded from Secha site. There was no significant difference in crude fiber content of *M. oleifera* leaf samples ($P > 0.05$) from the two agro-ecological zones. The fiber content of *M. oleifera* leaves powder was quite low when compared with similar data reported by Ijarotimi et al. (2013). Dietary fiber, the indigestible cell wall component of plant materials, plays an important role in human health (Wani et al., 2014). Epidemiological studies have shown that high dietary fiber intake helps to prevent or treat hyperlipidemia, cardiovascular disease, hypertension, obesity, certain cancers, gastrointestinal disorders and diabetes (Ijarotimi et al., 2013).

The crude lipid content of *M. oleifera* leaves powder from Secha and Karat was 7.11 and 7.35%, respectively. The higher lipid content was recorded for the Karat *M. oleifera* leaf samples (7.35%) and the lower lipid content for the Secha leaf samples (7.11%). There was no significant difference in crude lipid contents of *M. oleifera* leaf samples ($P > 0.05$) from the two agro-ecological zones. The crude lipid (7.35%), which was recorded from Karat *M. oleifera* leaf samples, was comparatively higher compared to values obtained in similar research with crude lipid content values of 6.73% (Melesse et al., 2011).

The crude protein contents from the Secha and Karat *M. oleifera* leaves powder were 24.80 and 24.30%, respectively. The higher crude protein content was recorded for the Secha *M. oleifera* leaf samples (24.80%) and the lower crude protein content for the Karat leaf samples (24.30%). There was no significant difference in crude protein contents of *M. oleifera* leaf samples ($P > 0.05$) from the two agro-ecological zones. The results indicated that *M. oleifera* leaves from the Secha contained appreciable amount of crude protein content (24.80%) and was comparatively higher than that of similar studies (Sanchez et al., 2006) for the same Moringa species (22.8%). Other studies have reported variable protein contents ranging between 16 and 40% (Shad et al., 2016; Sanchez-Machado et al., 2010). This level of crude protein content is of particular nutritional significance as it may meet animal's protein and energy requirements and boost the immune system against disease (Melesse et al., 2012).

***M. stenopetala* leaves powder from Sikela and Gato**

As indicated in Table1, the moisture contents of *M. stenopetala* leaves powder ranges between 7.92 and 7.73%. The result of the study indicated that dried

Moringa stenopetala leaves from the Sikela contained higher moisture content (7.92%) and the lower moisture content was recorded from Gato leaf samples (7.73%). There was no significant difference in moisture contents of *M. stenopetala* leaf samples ($P > 0.05$) from the two agro-ecological zones.

The total ash contents of *M. stenopetala* leaves powder ranges between 14.90 and 14.10%. The higher ash content was recorded from Sikela *M. stenopetala* leaf samples (14.90%) and the lower ash content from Gato leaf samples (14.10%). There was no significant difference in ash contents of *M. stenopetala* leaf samples ($P > 0.05$) from the two ecological zones. High ash content of (14.90%) from the Sikela *M. stenopetala* leaves powder in this study was comparable with that of similar study (Melesse et al., 2011) for the same Moringa species was found to be 14.80%.

Crude fiber of the *M. stenopetala* leaves powder ranged from 5.03 to 5.87%. Higher crude fiber (5.87%) was recorded from Gato site and lower 5.03% was recorded from Sikela site. There was no significant difference in ash contents of *M. stenopetala* leaf samples ($P > 0.05$) from the two agro-ecological zones. The fiber content of *M. stenopetala* leaves powder was quite low when compared with similar data reported by Ijarotimi et al. (2013).

The crude lipid contents for *M. stenopetala* leaves powder ranges between 3.65 and 4.29%. The higher crude lipid content was recorded for the Gato *M. stenopetala* leaf samples (4.29%) and the lower crude lipid content for the Sikela leaf samples (3.65%). There was no significant difference in crude lipid contents of *M. stenopetala* leaf samples ($P > 0.05$) from the two ecological zones. The average crude lipid content in *M. stenopetala* leaf samples from the Gato (4.29%) was comparatively higher than that of related study (Melesse et al., 2011) for the same Moringa species found (3.36%).

The crude protein content of *M. stenopetala* leaves powder ranges between 27.30 and 30.20%. The higher crude protein content was recorded for the Gato *M. stenopetala* leaf samples (30.20%) and the lower crude protein content for the Sikela leaf samples (27.30%). There was no significant difference in crude protein contents of *M. stenopetala* leaf samples ($P < 0.05$) from the two agro-ecological zones. The average crude protein content in *M. stenopetala* leaf samples from the Gato (30.20%) was comparatively higher than that of similar study (Melesse et al., 2011) for the same Moringa species found 26.6%.

All in all, there was no as such significant difference in nutritional composition of the two Moringa species grown in the two agro-ecological zones; this might be due to the lesser effect of variation in agro-ecological zones on compositions of nutrition of Moringa species. Therefore, other factors such as age, maturity of Moringa trees, soil conditions and so on might plays a major role in variation of nutritional as well as mineral composition of the species.

In addition, the proximate compositions of the two species have shown increment in their levels as compared with similar studies; in particular, the moisture content of the leaves was relatively lower and depicted higher values for the rest of proximate compositions (ash content, crude lipid, and crude fiber) in an indirect relationship as it decreases.

***M. oleifera* and *M. stenopetala* leaves powder from Secha and Sikela**

As indicated in Table 1, the moisture contents of *M. oleifera* leaves powder from Secha was 6.88% and *M. stenopetala* leaves from the Sikela contained moisture content of 7.92%. Higher moisture content was recorded for the Sikela *M. stenopetala* leaf samples (7.92%). There was no significant difference in moisture contents of the two species ($P > 0.05$) with in the same agro-ecological zones.

The total ash contents of *M. oleifera* leave powder from Secha 15.30%. The lower ash content was recorded for the Sikela *M. stenopetala* leaf sample (14.90%). There was no significant difference in ash contents of the two leaf samples ($P > 0.05$) with in the same agro-ecological zones. High ash content of (15.30%) from the Secha *M. oleifera* leaves powder in this study was comparatively higher when compared to related study for the same Moringa species (13.20%). However, the ash content of *M. stenopetala* leaves from the Sikela was comparable for the same Moringa species which was found to be 14.60% (Melesse et al., 2012).

The crude fiber contents of *M. oleifera* leave powder from Secha 5.51%. The crude fiber content was recorded for the Sikela *M. stenopetala* leaf samples (5.03%). There was no significant difference in crude fiber contents of the two leaf samples ($P > 0.05$) with in the same agro-ecological zones.

The crude lipid contents for *M. oleifera* leaves powder from the Secha was 7.11% and the lower crude lipid content was recorded for the Sikela *M. stenopetala* leaf samples (3.65%). There was significant difference in crude lipid contents of the two species ($P < 0.05$) with in the same agro-ecological zones. The average crude lipid content in *M. oleifera* leaf samples from the Secha (7.11%) was comparatively lower compared to similar study for the same Moringa species found (10.40%). However, the crude lipid content of *M. stenopetala* leaves from the Sikela (3.65%) was comparatively lower than that of similar study for the same Moringa species was found to be 10.70% (Melesse et al., 2012).

The crude protein content of *M. oleifera* leaves powder from the Secha was 24.80%. The higher crude protein content was recorded for the Sikela *M. stenopetala* leaves sample (27.30%). There was no significant difference in crude protein contents of the two species ($P > 0.05$) with in the same agro-ecological zones. The average crude protein content in *M. oleifera* leaf samples

from the Secha (24.80%) was comparatively lower than the related study for the same Moringa species found 29.0% (Melesse et al., 2012).

***M. oleifera* and *M. stenopetala* leaves powder from Karat and Gato**

As indicated in Table 1, the moisture content for the Karat *M. oleifera* leaf samples were (6.60%) and *M. stenopetala* leaves from the Gato contained moisture content of (7.73%). Higher moisture content was recorded from Gato *M. stenopetala* leaf samples (7.73%). There was no significant difference in moisture contents of the two species ($P > 0.05$) with in the same agro-ecological zones.

The total ash contents of *M. oleifera* leaves powder from the Karat was 15.60%. The lower ash content was recorded from Gato *M. stenopetala* leaf samples (14.10%). There was significant difference in ash contents of the two species ($P < 0.05$) with in the same agro-ecological zones. High ash content of (15.60%) from the Karat *M. oleifera* leaves powder in this study was comparatively higher than that of for the same Moringa species was found to be 13.20%. However, the ash content of *M. stenopetala* leaves from the Gato (14.10%) was comparable from similar study for the same Moringa species was found to be 14.60% (Melesse et al., 2012).

The crude fiber contents of *M. oleifera* leaves powder from Karat was 6.13%. The lower crude fiber content was recorded from Gato *M. stenopetala* leaf samples (5.87%). There was no significant difference in crude fiber contents of the two leaf samples ($P > 0.05$) with in the same agro-ecological zones.

The crude lipid contents for *M. oleifera* leaves powder from the Karat was 7.35%. Lower crude lipid content was recorded for the Gato *M. stenopetala* leaf samples (4.29%). There was significant difference in crude lipid contents of the two species ($P < 0.05$) with in the same agro-ecological zones. The average crude lipid content in *M. oleifera* leaf samples from the Karat (7.35%) was comparatively lower than that of related study for the same Moringa species found (10.4%). However, the crude lipid content of *M. stenopetala* leaves from the Gato (4.29%) was comparable to similar study for the same Moringa species was found to be 14.60% (Melesse et al., 2012).

The crude protein content of *M. oleifera* leaves powder from the Karat was 24.30%. Higher crude protein content was recorded for the Gato *M. stenopetala* leaf samples (30.20%). There was significant difference in crude protein contents of the two species ($P < 0.05$) with in the same agro-ecological zones. The average crude protein content in *M. oleifera* leaf samples from the Karat (24.30%) was comparatively lower than related study for the same Moringa species found (29.0%). However, the crude protein content of *M. stenopetala* leaves from the Gato (30.20%) was comparatively higher than that of

Table 2. Calculated carbohydrate and energy value of *Moringa oleifera* and *Moringa stenopetala* leaf powder from two different agro-ecological zones.

Sub-site	Sample type	Carbohydrate (%)	Energy value (kcal/g)
Secha	<i>M. oleifera</i>	40.4±3.21	264.3±5.23
Sikela	<i>M. stenopetala</i>	41.2±2.89	244.2±4.41
Karat	<i>M. oleifera</i>	40.0±2.76	263.7±6.01
Gato	<i>M. stenopetala</i>	37.8±2.53	244.6±3.96

Table 3. Concentration (mean ± SD, n=3, mg/kg air dry weight) of metals in *M. oleifera* and *M. stenopetala* leaf samples.

Metals	Metal concentration (mg/kg)				WHO permissible limit (mg/kg)
	Secha	Karat	Sikela	Gato	
	<i>M. oleifera</i>	<i>M. oleifera</i>	<i>M. stenopetala</i>	<i>M. stenopetala</i>	
K	12160±779.70	9570±21.0	12247±434.90	14047± 97.14	Not specified
Na	1296±101.5	1287±108.1	1293± 99.02	1298±99.50	Not specified
Mg	4370±120.0	4273.3±215.0	4550±310.5	4500±242.7	Not specified
Ca	19026±648.30	18803±114.0	18342±1010.0	18230±990.2	Not specified
Mn	72.37±3.37	76.77± 0.85	86.13±2.19	87.53±1.40	2.0 ^b
Zn	31.87±2.11	21.30±2.09	57.63±4.45	27.90±1.59	27.4 ^b
Fe	81.60±1.14	81.37±2.11	80.03±2.50	82.30±2.65	20.0 ^b
Cu	5.10±0.20	3.90±0.53	3.43±0.15	4.13±0.15	3.0 ^b

^bsource: FAO/WHO (2001).

related study for the same *Moringa* species was found to be 28.0% (Melesse et al., 2012).

The variations in ash, crude lipid and protein contents of the reported values may be due to different ages of trees, and possibly due to different stages of maturity (Yang et al., 2006).

Carbohydrate and energy values

The calculated carbohydrate and energy values for *M. oleifera* and *M. stenopetala* leaves powder collected from the four sub-sites were reported in Table 2. The %carbohydrate of *Moringa* species from Sikela, Secha, Karat and Gato were calculated using Equation 5 and found to be 40.4, 41.2, 40.0 and 37.8, respectively. There was no significant difference in %carbohydrate of *M. stenopetala* and *M. oleifera* leave samples ($P > 0.05$) from the two agro-ecological zones. The energy value (kcal/g) of *Moringa* leaves were also calculated as 264.3 (Secha), 244.2 (Sikela), 263.7 (Karat) and 244.6 (Gato). The result of energy value calculated for both *Moringa* species were found to be lower than related studies (Melesse et al., 2011).

Elemental compositions of *Moringa* species

Metal levels in the *M. oleifera* leaf samples from Secha and Karat

As shown in Table 3, the mean potassium concentration

in the *M. oleifera* leaves samples were 12160 and 9570 mg/kg for Secha and Karat, respectively. There were significant differences at ($P < 0.05$) among the mean concentrations of K metal in the leaf samples. These differences could probably be the result of plant nutrition, climate and soil conditions (Hamurcu et al., 2010).

The sodium concentration of the *M. oleifera* leaf samples analyzed (Table 3) were 1296 and 1287 mg /kg for Secha and Karat, respectively. F-test showed that there were no significant differences ($P > 0.05$) among the mean concentrations of Na metal in the leaf samples.

Magnesium concentrations were found to be 4370 and 4273.3 mg/kg in the Secha and Karat leaf samples, respectively (Table 3), which was greater than the leaf samples of the Karat site. The concentrations of Mg were not significantly different ($P > 0.05$) in the leaf samples.

The average concentrations of calcium in the *M. oleifera* leaf samples were found to be 19026 and 18803.30 mg/kg in the Secha and Karat leaf samples, respectively (Table 3). Ca concentration was greater in the leaf samples of the Secha. From the statistical F-test, there was no significant differences ($P > 0.05$) in Ca concentration were observed among the leaf samples analyzed.

Concentration of manganese was found to be 72.37 and 76.77 mg/kg in the Secha and Karat leaf samples, respectively (Table 3). Mn concentration was greater in the leaf samples of the Karat. There was no Significant difference ($P > 0.05$) in concentrations of Mn were found between the leaf samples from the results of statistical F-

test.

Both Mn concentrations were below the tolerable limit of 500 mg/kg, dry weight (Council of Europe, 2002). The critical concentration of Mn is 300 to 500 ppm dry weight and the estimated safe and adequate daily dietary intake in adults is 11 mg/day (Khan et al., 2008).

Zinc, analyzed in the *M. oliefera* leaf samples was 31.87 and 21.3 mg /kg in the case of Secha and Karat, respectively (Table 3). The statistical F-test showed no significant variation ($p > 0.05$) between the tested leaf samples. The amounts of Zn were below the US Recommended Daily Allowance (RDA) which is 15 mg/day for males and 12 mg/day for females and estimated maximum intake of 77 mg/day.

Iron was determined in the *M. oliefera* leaf samples and was found to be 81.60 and 81.37 mg/kg in leaf samples of Secha and Karat, respectively (Table 3). The statistical F-test showed no significant variation ($p > 0.05$) between the tested leaf samples. Iron is an essential micronutrient required for human growth and development. The results showed that the Moringa leaves can be a good source of iron. The values are in accordance to recommended daily allowance of iron 100 to 130 mg/kg for children; 70 mg/kg for men and 120 to 160 mg/kg for women and feeding mothers (Ijarotimi et al., 2013).

Concentrations of copper in *M. oliefera* leaf samples were found to be 5.10 and 3.90 mg/kg in the Secha and karat sites, respectively (Table 3). The greater concentration of Cu was found in leaf samples of Secha site. Both concentrations were below the maximum permissible limit of 40 mg/kg dry weight (FAO/WHO, 1995). Therefore, the plant has no risk. From the statistical F-test, significant differences ($P < 0.05$) in Cu concentration were observed among the leaf samples analyzed.

Metals levels in the *M. stenopetala* leaf samples from Sikela and Gato

The mean potassium concentration in the *M. stenopetala* leaves samples were found to be 12247 and 14047 mg/kg for Sikela and Gato, respectively (Table 3). There were significant differences at ($P < 0.05$) among the mean concentrations of K metal in the leaf samples. These differences could probably be the result of plant nutrition, climate and soil conditions (Hamurcu et al., 2010).

The sodium concentration of the *M. stenopetala* leaf samples analyzed were 1293 and 1298 mg/kg for Sikela and Gato, respectively (Table 3). F-test showed that there were no significant differences at ($P > 0.05$) among the mean concentrations of Na metal in the leaf samples.

Magnesium concentrations in the leaf samples were found to be 4550 and 4500 mg/kg in Sikela and Gato, respectively (Table 3). This was greater in the leaf samples of the Sikela site. There were no significant difference ($P > 0.05$) in concentration of Mg between the

leaf samples.

The average concentrations of calcium in the *M. stenopetala* leaf samples were found to be 18341.70 and 18230 mg/kg in the Sikela and Gato, respectively (Table 3). Ca concentration was greater in the leaf samples of the Sikela site. From the statistical F-test, there were no significant differences ($P > 0.05$) in Ca concentration were observed among the leaf samples analyzed. High concentration of Ca is important because of its role in bones, teeth, muscles system and heart functions. The present study show satisfactory level of Ca accumulation as in earlier reports Moringa leaf samples (Abdul et al., 2012).

Concentrations of manganese in the *M. stenopetala* leaf samples of were found to be 86.13 and 87.53 mg /kg in the Sikela and Gato, respectively (Table 3). Mn concentration was greater in the leaf samples of the Gato site. There was no significant difference ($P > 0.05$) concentrations of Mn were found between the leaf samples from the results of statistical F-test. For medicinal plants the WHO (FAO/WHO, 1984) limit has not yet been established for Mn. The range of Mn concentration in selective medicinal plants of Egypt was between 44.6 to 339 ppm (Jabeen et al., 2010). The concentration of *M. stenopetala* under the present study is in the range of 10 to 1800 ppm, indicating that all the concentration of Mn in the plants studied is around the normal range.

Zinc, analyzed in the *M. stenopetala* leaf samples were found to be 57.63 and 27.90 mg/kg in the case of Sikela and Gato, respectively (Table 3). Zn concentration was greater in the leaf samples of the Sikela site. The statistical F-test showed significant variation ($p < 0.05$) between the tested leaf samples. The permissible limit set by FAO/WHO in edible plants was 27.4 ppm.

According to Jabeen et al. (2010), the range of Zn in agricultural products should be between 15 to 200 mg/kg. Iron was determined in the *M. stenopetala* leaf samples and were found to be 80.03 and 82.30 mg/kg in leaf samples of Sikela and Gato, respectively (Table 3). Zn concentration was greater in the leaf samples of the Gato site. The statistical F-test showed no significant variation ($p > 0.05$) between the tested leaf samples. The permissible limit set by FAO/WHO (FAO/WHO, 1984) in edible plants was 20 ppm. For medicinal plants the WHO (FAO/WHO, 1984) limit has not yet been established for iron. The range of iron in selective medicinal herbs of Egypt in the study carried out was between 261 to 1239 ppm (Jabeen et al., 2010). The concentration of Fe in the *M. Stenopetala* is around the normal range for the element when compared with the medicinal herbs of Egypt.

Concentrations of Copper in *M. stenopetala* leaf samples were found to be 3.43 and 4.13 mg/kg in the Sikela and Gato, respectively (Table 3). The greater concentration of Cu was found in leaf samples of Gato site. Both concentrations were below the maximum

Table 4. pH of the soils (Mean $\pm$ SD, n=3).

Sample site	pH (H ₂ O)
Secha	7.86 $\pm$ 0.10
Sikela	8.11 $\pm$ 0.11
Karat	8.16 $\pm$ 0.17
Gato	8.29 $\pm$ 0.07

Table 5. Concentration (mean $\pm$ SD, n = 3, mg/kg air dry weight) of metals in soil samples.

Metals	Metal concentration (mg/kg)				WHO permissible limit (mg/kg)
	Secha	Karat	Sikela	Gato	
	Soil	Soil	Soil	Soil	
K	3523 $\pm$ 205.5	1540 $\pm$ 134.50	3343.30 $\pm$ 236.90	2930 $\pm$ 91.65	NA
Na	1980 $\pm$ 87.18	1623 $\pm$ 94.52	2776.70 $\pm$ 76.38	1773.30 $\pm$ 80.02	NA
Mg	3606.7 $\pm$ 66.58	3533 $\pm$ 45.09	4253.30 $\pm$ 197.60	4463.3 $\pm$ 204.29	NA
Ca	17210 $\pm$ 2025.0	17633 $\pm$ 985.3	17513.30 $\pm$ 1746	17340 $\pm$ 374.03	NA
Mn	84.53 $\pm$ 3.24	11.0 $\pm$ 0.10	5.33 $\pm$ 0.25	29.67 $\pm$ 3.79	2000 ^{bc}
Zn	36.57 $\pm$ 2.40	68.27 $\pm$ 8.44	74.23 $\pm$ 9.82	77.87 $\pm$ 26.23	300 ^a
Fe	20.27 $\pm$ 2.05	14.40 $\pm$ 1.22	21.0 $\pm$ 1.87	65.67 $\pm$ 8.39	50000 ^{bc}
Cu	1.27 $\pm$ 0.15	0.83 $\pm$ 0.12	1.03 $\pm$ 0.15	10.23 $\pm$ 0.68	100 ^a

^aSource: Ewers (1991); ^bsource: FAO/WHO, (2001); ^cSource: Pendias and Pendias, (1992); NA = Not available.

permissible limit of 40 mg/kg dry weight (FAO/WHO, 1995). From the statistical F-test, significant differences ($P < 0.05$) in Cu concentration were observed among the leaf samples analyzed. The permissible limit set by FAO/WHO for edible plants was 3.00 ppm (Jabeen et al., 2010). For medicinal herbs the WHO (FAO/WHO, 1984) limit has not yet been established for copper. In medicinal plants the permissible limit of copper set by China and Singapore were 20 and 150 ppm, respectively. The metal concentration of *M. stenopetala* was found to have below permissible limits of copper set by China and Singapore.

pH of soil samples

The mean pH values of soils from Secha and Karat

The mean pH values of the soils where *M. oliefera* was planted ranges between 7.86 $\pm$ 0.10 and 8.16 $\pm$ 0.17 (Table 4). Higher pH was recorded for the Karat soil sample (8.16 $\pm$ 0.17) and lower pH for Secha soil sample (7.86 $\pm$ 0.10). The analysis of variance showed that there was no significant difference in pH ($P > 0.05$). The pH of the soil from both sites, where *M. oliefera* planted was within the slightly alkaline range of the pH scale. This was in line with the findings of Anjorin et al. (2010) on the soil survey of Abuja.

The mean pH values of soils from Secha and Karat

The mean pH values of the soils where *M. stenopetala*

was planted ranges between 8.11 $\pm$ 0.11 and 8.29 $\pm$ 0.07 (Table 4). Higher pH was recorded for the Gato soil sample (8.29 $\pm$ 0.07) and lower pH for the Sikela soil sample (8.11 $\pm$ 0.11). The analysis of variance showed that there was no significant difference in pH ($P > 0.05$). The pH of the soils from both sites, where *M. stenopetala* planted was within the slightly alkaline range of the pH scale. This was in line with the findings of Anjorin et al. (2010) on the soil survey of Abuja.

Elemental compositions of soils

Metals levels in the soil samples from Secha and Karat

As shown in the Table 5, the mean concentrations of K, Na, Mg, Ca, Mn, Zn, Fe and Cu were 3523, 1980, 3606.70, 17210, 84.53, 36.57, 20.27 and 1.27 mg/kg, respectively in the Secha soil samples; and 1540, 1623.30, 3533.30, 17633.30, 11.0, 68.27, 14.40 and 0.83 mg/kg, respectively in the Karat soil samples. The concentrations of all metals were greater in the Secha soil samples except that of Ca and Zn which was greater in the Karat soil samples.

F-test showed significant differences ($P < 0.05$) among the analyzed soil samples for the mean concentrations of all metals in except Mg, Ca and Zn. These differences could probably be the result of climate and soil conditions (Hamurcu et al., 2010).

Metals levels in the soil samples from Sikela and Gato

As shown in the Table 5, the mean concentrations of K, Na, Mg, Ca, Mn, Zn, Fe and Cu were 3343.30, 2776.70, 4253.30, 17513.30, 5.33, 74.23, 21.0 and 1.03 mg/kg, respectively in the Sikela soil samples; and 2930, 1773.30, 4463.30, 17340, 29.67, 77.87, 65.67 and 10.23 mg/kg respectively in the Gato soil samples. The concentrations of all metals were lower in the Sikela soil samples except that of K, Na and Ca which was lower in the Gato soil samples. F-test showed no significant differences ($p > 0.05$) among the analyzed soil samples for the mean concentrations of all metals except Na, Mn and Fe. These differences could probably be the result of climate and soil conditions (Hamurcu et al., 2010).

Conclusion

The data derived from proximate and mineral composition of *M. oleifera* and *M. stenopetala* leaves collected from two different agro-ecological zones indicated that the plant leaves are rich in nutrients and has potential to be used as a feed additive for human and animal. These include serving as a protein, fats, fiber, carbohydrate and mineral resource feed formulations. There was no as such significant difference in nutritional composition of the two Moringa species grown in the two agro-ecological zones. It is recommended that further investigations on vitamin, amino acid profiles and anti-nutritional factors of fresh Moringa leaves be carried.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

REFERENCES

- Abdul G, Zulfaqar A, Muhammad I, Mehwish M, Saira P (2012). Estimation of macro and micro nutrients in some important medicinal plants of Soon Valley, District, Khushab, Pakistan. *Afr. J. Biotechnol.* 11:14386-14391.
- Agena A (2009). Screening Moringa accessions for resistance to Moringa moth, *Noorda blitealis* walker (Crambidae: Nooridae). *Ind. J. For.* 32:243-250.
- Al-Kharusi LM, Elmardi MO, Ali A, Al-Said FAJ, Abdelbasitand KM, Al-Rawahi S (2009). Effect of mineral and organic fertilizers on the chemical characteristics and quality of date fruits. *Int. J. Agric. Biol.* 11:290-296.
- Amaechi NC (2009). Nutritive and anti-nutritive evaluation of wonderful kola (*Bucchozia coricea*) seeds. *Pak. J. Nutr.* 8:1120-1122.
- Anjorin TS, Ikokoh P, Okolo S (2010). Mineral composition of Moringa oleifera leaves, pods and seeds from two regions in Abuja, Nigeria. *Int. J. Agric. Biol.* 12:431-434.
- Anthonia OO (2012). Evaluation of antimicrobial properties and nutritional potential of Moringa leaves in South-Western Nigeria. *Malays. J. Microbiol.* 8:59-67.
- AOAC (1990). Official Methods of Analysis. Arlington, Virginia USA: Association of Official Analytical Chemist, Inc.
- AOAC (2000). Official Methods of Analysis. Arlington, Virginia USA: Association of Official Analytical Chemist, Inc.
- Armelle De SS, Melanie B (2010). Growing and Processing of Moringa Leaves. Moringa Association of Ghana.
- Bosch CH (2004). *Moringa stenopetala* Lam. In: Grubben GJH, Denton OA (Eds.), PROTA 2: (Plant Resources of Tropical Africa/ Resources végétales de l'Afrique tropicale, Wageningen, Netherlands.
- Busani M, Masika PJ, Hugo A, Muchenje V (2011). Nutritional characterization of Moringa (*Moringa oleifera* Lam.) leaves. *Afr. J. Biotechnol.* 10:12925-12933.
- Council of Europe (2002). Guide Lines on Metals and Alloys Used as Food Contact Materials, Council of Europe Press.
- Ewers U (1991). Standards, Guidelines and Legislative Regulations Concerning Metals and Their Compounds. In: E. Merian (Ed.), Metals and Their Compounds in the Environment: Occurrence, Analysis and Biological Relevance, 3 volume, Merian, E, Anke, M, Ihant, M and Stoeppler, M (eds.), Wiley-VCH, Weinheim.
- FAO/WHO (1984). Contaminants. In: codex Alimentarius, vol. XVII, Edison 1. FAO/WHO, Codex Alimentarius Commissions, Rome, Italy.
- FAO/WHO (1995). Codex General Standard for Contaminants and Toxins in Food and Feed (CODEX STAN 193-1995), Vienna.
- FAO/WHO (2001). (Codex Alimentarius Commission), Food Additives and Contaminants, Joint FAO/WHO Food Standards Program: ALINORM 01/12A:1-289, Vienna.
- Grubben GJH, Denton OA (2004). Vegetables: Plant Resources of Tropical Africa Part 2, Foundation/Buckhuys Publishers/ CTA.
- Hamurcu M, Musa Ozcan M, Dursun N, Gezgin S (2010). Mineral and heavy metal levels of some fruits grown at the roadsides. *Food Chem. Toxicol.* 48:1767-1770.
- Ijarotimi OS, Adeoti OA, Ariyo O (2013). Comparative study on nutrient composition, phytochemical, and functional characteristics of raw, germinated, and fermented Moringa oleifera seed flour. *Food Sci. Nutr.* 1:452-463.
- Jabeen S, Shah MT, Khan S, Hayat MQ (2010). Determination of major and trace elements in ten important folk therapeutic plants of Haripur basin, Pakistan. *J. Med. Plant Res.* 4:559-566.
- James S (1995). Analytical Chemistry of Food. Glawgow, UK: Blackie Academic and Professional.
- Khan SHA, Khan L, Hussain I, Marwat KB, Akhtar N (2008). Profile of heavy metals in selected medicinal plants. *Pak. J. Weed Sci. Res.* 14:101-110.
- Mahan MR, Konan NY, Sidibe D, Coulibaly A, Ezoua P, Chatigre KO, Biege GHM (2016). Nutritive compounds from leaves of *Moringa oleifera* L. and beans of *Vigna unguiculata* W. for improvement of the meal deriving with new shoots of *Borassus aethiopum* M. in Côte d'Ivoire. *Int. J. Environ. Agric. Res.* 2:64-74.
- Martin EA, Coolidge AA (1978). Nutrition in action. 4th ed. Holt, R and Wilson Co., New York.
- Melesse A, Berihun K (2013). Chemical and mineral compositions of pods of *Moringa stenopetala* and *Moringa oleifera* cultivated in the lowland of Gamogofa Zone. *J. Environ. Occup. Sci.* 2:33-38.
- Melesse A, Bulang M, Kluth H (2009). Evaluating the nutritive values and *in vitro* degradability characteristics of leaves, seeds and seedpods from *M. stenopetala*. *J. Sci. Food Agric.* 89:281-287.
- Melesse A, Steingass H, Boguhn J, Schollenberger M, Rodehutschord M (2012). Altitudinal and seasonal variations in nutritional composition of leaf and green pod fractions of *Moringa stenopetala* and *Moringa oleifera*. *Agroforest. Syst.* 86:505-518.
- Melesse A, Tiruneh W, Negesse T (2011). Effects of feeding *Moringa stenopetala* leaf meal on nutrient intake and growth performance of Rhode Island Red chicks under tropical climate. *Trop. Subtrop. Agroecosys.* 14:485-492.
- Muhammad A, Dangoggo SM, Tsafe AI, Itodo AU, Atiku FA (2011). Proximate, mineral and anti-nutritional factors of *Gardenia aquilla* (*Gauden dutse*) fruit pulp. *Pak. J. Nutr.* 10:577-581.
- Nielsen SS (2010). Food Analysis, Food Science Texts Series. New York: Springer.
- Ogbe AO, John PA (2011). Proximate study, mineral and anti-nutrient composition of *Moringa oleifera* leaves and potential benefits in poultry nutrition and health. *J. Microbiol. Biotechnol. Food Sci.* 1:296-308.
- Onu PN, Aniebo AO (2011). Influence of *Moringa oleifera* meal on the

- performance and blood chemistry of starter broilers. Ind. J. Fundam. App. Life Sci. 1:38-44.
- Pendias AK, Pendias H (1992). Elements of group VIII. In. Trace elements in soils and plants. Boca Raton: CRC Press. Pp. 271-276.
- Sanchez NR, Ledin S, Ledin I (2006). Biomass production and chemical composition of *Moringa oleifera* under different management regimes in Nicaragua. Agroforest. Syst. 66:231-242.
- Sanchez-Machado DI, Nunez-Gastelum JA, Reyes-Moreno C, Ramirez-Wong B, Lopenz-Cervantes J (2010). Nutritional Quality of edible Parts of *Moringa oleifera*. Food Anal. Methods 3:175-180.
- Shad AA, Bakht J, Shah HU and Hayat Y (2016). Antioxidant activity and nutritional assessment of under-utilized medicinal plants. Pak. J. Pharm. Sci. 29:2039-2045.
- Tetteh ONA (2008). Effects of blanching and dehydration methods on the quality of Moringa leaf powder used as herbal green tea. [Master's thesis], Kwame Nkrumah University, Ghana.
- Wani SA, Shah TR, Bazaria B, Nayik GA, Gull A, Muzaffar K, Kumar P (2014). Oats as a functional food: a review. Univ. J. Pharm. 3:14-20.
- Yang RY, Tsou SCS, Lee TC, Chang LC, Kuo G, Lai PY (2006). Moringa a novel plant rich in antioxidants bio-available iron and nutrients. Am. Chem. Soc. Symp. Ser. 925:224-239.