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FULL ARTICLE

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The biochemical composition of the leaves and seeds meals of *moringa* species as non-conventional sources of nutrients

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Abstract

Some physicochemical properties of the oil, crude protein, sugars, and amino acids of the leaves and seed meals of two Moringa species were determined and compared using Student's *T*-test. The oil properties and fatty acid composition were significantly (at either $p \leq .01$ or $p \leq .05$) varied between the two species. The sterols and tocopherols contents of the species oil differed significantly. Most of the sterols were not detected in *Moringa oleifera* oil. The sugars contents were significantly different between the two species. The protein contents of *M. oleifera* leaves and seed meals were significantly higher than those of *Moringa peregrina*. Compared with *M. peregrina*, the *M. oleifera* leaves and seed meals had significantly higher amounts of amino acids. The most concentrated amino acids in the *M. oleifera* leaves and seed meals were glutamic acid, aspartic acid and leucine whereas those in *M. peregrina* were threonine, serine, and proline.

Practical applications

Moringa seed kernels contain a significant amount of oil. Moringa leaves are a good human food and animal feed. Various parts of *Moringa oleifera* are incorporated into the traditional food of humans. The leaves of *Moringa* are a good source of protein, vitamin A, B, and C. The leaf of *M. oleifera* contains crude protein up to 25%. In many tropical and subtropical countries, various parts of *M. oleifera* (leaves, fruits, immature pods, and flowers) are incorporated into the traditional food of humans.

KEYWORDS

amino acid, fatty acid, moringa, sterol, tocopherol

1 | INTRODUCTION

Moringa oleifera, a small deciduous tree, is the most widely naturalized species of Moringaceae family and is commonly known as the horseradish or drumstick tree (Morton, 1991; Sengupta & Gupta, 1970; Vlahov, Chepkwony, & Ndalut, 2002). In many tropical and subtropical countries, various parts of *M. oleifera* (leaves, fruits, immature pods, and flowers) are incorporated into the traditional food of humans (Anhwange, Ajibola, & Oniye, 2004; Siddhuraju & Becker, 2003). Leaves of the moringa tree are the preferred part for use in animal diets as leaf meal (Abbas, 2013). The leaves of *M. oleifera* are a good source of protein, vitamin A, B, and C and mineral such as calcium and iron (Dahat, 1988). The flowers, leaves and roots of *M. oleifera* are used for the treatment of ascites, rheumatism, and venomous bites and as cardiac and circulatory stimulants in folk remedies (Anwar & Bhanger, 2003; Anwar & Rashid, 2007; Hartwell, 1995). Moringa seed kernels contain a significant amount of oil that is commercially known as "Ben oil" or "Behen oil." The Ben oil was errone ously reported to be resistant to rancidity and used extensively in the "enfleurage" process (Ndabigengeser & Narasiah, 1998). The leaf of *M. oleifera* contains erude protein up to 25% (Makkar & Becker, 1996) yet little research is on going to develop Moringa as a fodder tree and source of leaf protein concetrate for ruminants (Aye & Adegun, 2013). Moreover, it is widely cultivated in different countries (Fahey, 2005). *M. oleifera* is also known for its

antioxidant activity, essentially due to the presence of high amounts of polyphenols (Fahey, 2005). *Moringa oleifera* is a widely grown crop in India, Ethiopia, the Philippines, and Sadan. The tree is being grown in West, East, and South Africa and in tropical Asia, Latin America, The Caribbean, Florida, and the Pacific Islands (Fahey, 2005). Yameogo, Bengaly, Savadogo, Nikiema, and Traore (2011) reported that, on a dry matter basis, *M. oleifera* leaves contained 27.2% protein, 5.9% moisture, 17.1% fat, and 38.6% carbohydrates. Makkar and Becker (1997) reported that the essential amino acid contents of the leaves and sulfur containing amino acids of the kernel were higher than the amino acid pattern of the FAO reference protein, but other essential amino acids of the kernel were deficient.

Vegetables are an important part of the human diet and a major source of biologically active substances such as vitamins, dietary fiber, antioxidants, and cholesterol-lowering compounds (Arabshahi, Devi, & Urooj, 2007; Madukwe, Ezeugwa, & Eme 2013). *Moringa oleifera* has in the past two decades been advocated as an excellent source of essential nutrients (protein, iron, calcium, vitamins, carotenoids and other phytochemicals (Fahey, 2005). Seed flour from *M. oleifera* is widely used as a natural coagulant for water treatment in developing countries (Santos, Argolo, Coelho, & Paiva, 2005). The seed cake remaining ofter oil extraction may be used as a fertilizer (Rashid, Anwar, Moser, & Knothe, 2008).

There are limited studies on the chemical properties of the seed and leaves of *M. oleifera* and *M. peregrina* and characterization of the oil extracted from the seeds. Therefore, current study evaluated the pyhsicochemical properties of two *Moringa* species seed oil and leaves.

2 | MATERIAL AND METHODS

2.1 | Material

Moringa oleifera leaves, cake, and oil were obtained from a demonstration farm, Khartoum North, Sudan while that of *M. peregrina were obtained from* a demonstration farm, Southern Region, Kingdom of Saudi Arabia. Petroleum ether (40–60C) was of analytical grade (>98%; Merck, Darmstadt, Germany). Heptane and tert-butyl methyl ether were of HPLC grade (Merck, Darmstadt, Germany). Tocopherol and tocotrienol standard compounds were purchased from CalBiochem (Darmstadt, Germany). Unless otherwise stated all reagents used in this study were of ragent grade.

2.2 | Methods

2.2.1 | Oil content

The oil content was determined according to the method ISO 659:1998 (ISO 1998). About 2 g of the seeds were ground in a ball mill and extracted with petroleum ether in a Twisselmann apparatus (İldam Laboratuary, Ankara-Turkey) for 6 hr. The solvent was removed by a rotary evaporator (Heidolph Laborota 4001, Schwabach/Germany) at 40C and 25 Torr. The oil was dried by a stream of nitrogen and stored at −20C until used.

2.2.2 | Fatty acid composition

The fatty acid composition was determined following the ISO standard ISO 5509:2000 (ISO 2000). In brief, one drop of the oil was dissoleved in 1 mL of *n*-heptane, 50 μg of sodium methylate was added, and the closed tube was agitated vigorously for 1 min at room temperature. After addition of 100 μL of water, the tube was centrifuged at 4,500 g for 10 min and the lower aqueous phase was removed. Then 50 μL of HCl (1 mol with methyl orange) was added, the solution was shortly mixed, and the lower aqueous phase was rejected. About 20 mg of sodium hydrogen sulphate (monohydrate, extra pure; Merck, Darmstadt, Germany) was added, and after centrifugation at 4,500 g for 10 min, the top *n*-heptane phase was transferred to a vial and injected in a Varian 5890 gas chromotograph with a capillary column, CP-Sil 88 (100 m long, 0.25 mm ID, film thickness 0.2 μm). The temperature program was as follows: from 155C; heated to 220C (1.5C/min), 10 min isotherm; injector 250C, detector 250C; carrier gas 36 cm/s hydrogen; split ratio 1:50; detector gas 30 mL/min hydrogen; 300 mL/min air, and 30 mL/min nitrogen; manual injection volume less than 1 μL. The peak areas were computed by the integration software, and percentages of fatty acid methyl esters (FAME) were obtained as weight percent by direct internal normalization.

2.2.3 | Tocopherols

For determination of tocopherols, a solution of 250 mg of oil in 25 mL of *n*-heptane was directly used for the HPLC. The HPLC analysis was conducted using a Merck-Hitachi low-pressure gradient system, fitted with a L-6000 pump, a Merck-Hitachi F-1000 fluorescence spectrophotometer (detector wavelengths for excitation 295 nm, for emission 330 nm), and a D-2500 integration system. The samples in the amount of 20 μL were injected by a Merck 655-A40 autosampler onto a Diol phase HPLC column 25 cm × 4.6 mm ID (Merck, Darmstadt, Germany) used with a flow rate of 1.3 mL/min. The mobile phase used was *n*-heptane/tert-butyl methyl ether (99 + 1, v/v (Balz, Schulte, & Their, 1992).

2.2.4 | Sterols

The sterol composition of the oils was determined following ISO/FIDS 12228:1999 (E) (ISO 1999). In brief, 250 mg of oil was saponified with a solution of ethanolic potassium hydroxide by boiling under reflux. The unsaponifiable matter was isolated by solid-phase extraction on an aluminium oxide column (Merck, Darmstadt, Germany) on which fatty acid anions were retained and sterols passed through. The sterol fraction was separated from unsaponifiable matter by thin-layer chromatograph (Merck, Darmstadt, Germany), er-extracted from the TLC material, and afterward, the composition of the sterol fraction was determined by GLC using betulin as internal standard. The compounds were separated on a SE 54 CB (Macherey-Nagel, Düren, Germany; 50 m long, 0.32 mm ID, 0.25 μm film thickness). Further parameters were as follows: hydrogen as carrier gas, split ratio 1:20, injection and detection temperature adjusted to 320C, temperature program, 245–260C at 5C/min. Peaks were identified either by standard compounds (β-sitosterol, campesterol, stigmasterol) by a mixture of sterols isolated

TABLE 1 Oil content, some physicochemical properties and fatty acid composition of *Moringa oleifera* and *peregrina* seed oils

Parameter	*Moringa* species		Mean difference
	oleifera	*peregrina*	
Oil (%)	40.98 ± 0.94	49.23 ± 0.78	8.25**
Physical properties			
Refractive index (40C)	1.45 ± 0.34	1.44 ± 0.41	0.01
Density (g/cm^3, 24C)	0.89 ± 0.06	0.87 ± 0.13	0.02*
Saponification value (mgKOH/gm oil)	181.00 ± 0.87	182.00 ± 0.73	1.00**
Iodine value (gm I_2/100 gm oil)	66.45 ± 0.76	68.38 ± 0.57	1.93**
Fatty acids (%)			
Saturated			
Palmitic acid (C16:0)	5.75 ± 0.56	8.54 ± 0.69	2.790**
Arachidic acid (C20:0)	4.40 ± 0.13	2.09 ± 0.07	2.310**
Behenic acid (C22:0)	6.98 ± 0.37	3.28 ± 0.11	3.700**
Unsaturated			
Oleic acid (cis Δ9-C18:1)	64.56 ± 1.64	73.90 ± 2.18	9.373**
Vaccenic acid (Δ11-C18:1)	6.00 ± 0.71	3.93 ± 0.52	2.070*
Linoleic acid (C18:2)	0.87 ± 0.08	0.45 ± 0.05	0.420**
Elaidic acid (trans Δ9-C18:1)	6.39 ± 0.78	3.37 ± 0.53	3.020**
Eicosenoic (C20:1)	2.30 ± 0.06	1.82± 0.05	0.480**
Palmitoleic acid (C16:1)	1.28 ± 0.07	1.95 ± 0.06	0.670**
Nervonic (C24:1)	1.47 ± 0.05	0.66± 0.07	0.810**

Values are means (±SD) of triplicate samples.
**$p \leq .01$.
*$p \leq .05$.

from rape seed oil (brassicasterol) or by a mixture of sterols isolated from sunflower oil (Δ7-avenasterol, Δ7-stigmasterol, and Δ7-campesterol). All other sterols were identified by GC-MS for the first time and afterward by comparison of the retention time.

2.2.5 | Proximate and sugar analyses

Determination of moisture and protein content were done according to AACC approved methods 44-15.02 and 46-30.01, respectively. Moisture was measured by heating the sample for 1 hr at 135C in a gravity oven (AACC International, 1999a). The nitrogen combustion method was used for determination of crude protein. The protein determination was made in Leco combustion analyzer and 6.25 was used as the conversion factor (AACC International, 1999b).The free sugar composition was determined by chromatographic methods according to Churms, Zweig, and Sherma (1982) and Kakehi and Honda (1989). The free sugars were derivatized to silyl ethers for separation and quantification by gas chromatography.

2.2.6 | Amino acid profile

Determination of Amino acid Profile of Samples: Amino acid profile was determined based on the method described by Spackman, Stein, and Moore (1980) using the Technicon Sequential Multi-sample amino acid Analyzer (TSM-1 Technicon Instrument Basingstoke, UK) using Norleucine as an internal standard. TSM is an automated instrument designed to separate, detect, and quantitate amino acids. It works maximally within a temperature range of 18.3–35C (65–95F) and humidity of 10–80%. The hydrolysate was vacuum-dried to remove the buffer solution before loading into the TSM. Compressed nitrogen was passed into the TSM to serve as a segmented stream flow of the amino acid which helps the analyzer detect any amino acid found and stop mix-up of amino acids. About 5–10 mL of sample was dispensed into the cartridge of the analyzer. The TSM analyzer is designed in such a way as to separate and analyze free acidic, neutral, and basic amino acids of the hydrolysate. The analysis lasted for 76 min (International, Horwitz, & Latimer, 2006; Nweke, Ubi, & Kunert, 2011).

2.3 | Statistical analyses

All analyses were carried out as three replications. Results of the research were analysed for statistical significance by analysis of variance (Püskülcü & İkiz, 1989).

3 | RESULTS AND DISCUSSION

Fatty acid composition of *M. oleifera* and *M. peregrina* seed oils are given in Table 1. The extracted oils were liquid at room temperature. The fatty acid profiles of the seed oil showed unsaturated and saturated fatty acid contents of 82.87 and 17.13% and 86.08 and 13.91% in *M.oleifera* and *M. peregrina*, respectively. The predominant fatty acid was oleic acid for both samples. *Moringa oleifera* and *M. peregrina* oil

contained 5.75 and 8.54% palmitic, 6.39 and 3.37% stearic, 64.56 and 73.90% oleic, 6.0% 3.93% 18:1D11, 4.40 and 2.09% 20:0 and 6.98 and 3.28% behenic acids. Moringa oil is characterized by a high content of oleic acid and belongs to the oleic acid oil category (Sonntag, 1982). The fatty acid compositions of samples are similar to that of *M. oleifera* Mbololo and Periyakulam 1 variety seed oils (Lalas & Tsaknis, 2002; Tsaknis et al., 1999a,b). In addition, behenic acid was found high in both oils. Due to high content of behenic acid of Moringa oil, addition of behenic acid can lighten chocolate texture and oily feel (Matsui, Okochi, & Kida, 2000), prevent solid roux from being whitened (Sakaguchi, Murayama, Hashimoto, & Kato, 1997) and provide excellent mouth feel and melt-down beheviour to semj-solid and solid fats (such as margarine, shortening, and foods containing semi-solid and solid fats) (Cain & Moore, 1995; Cain, Pierce, Schmidl, & Smith, 1996). Banerji Verma, and Pushpangadan (2003) reported that *M. oleifera* oil contained 5.0–9.7% palmitic, 2.0–2.7% palmitoleic, 0.8–2.7% stearic, 79.4–85.0% oleic, 1.3–2.3% linoleic, and 3.6–5.0% arachidic acid. In previous study the dominant saturated fatty acids of *M. oleifera* oil were palmitic acid (12.51%) and Lauric acid (1.97%) (Ashraf & Gilani, 2007). The percentages of other fatty acids in *M. oleifera* seed kernel oil were stearic acid (2.09%), linoleic acid (1.27%), and linolenic acid (1.75%). In addition, oleic acid (74.99%) was the most abundant of the unsaturated fatty acids found in *M. oleifera* seed kernel oil (Ashraf & Gilani, 2007). According to Compaore et al. (2011), the major saturated fatty acids were behenic, arachidic, stearic, and palmitic acids and the main unsaturated fatty acid is oleic acid with small amounts eicosenoic and palmitoleic acids of *M. oleifera*.

Moringa oleifera oil appears to be a potentially valuable and might be an acceptable substitute for high oleic oils like olive and high oleic sunflower oils as our dietary fats and it also could be used for various commodities of commercial attributes (Anwar, Ashraf, & Bhanger, 2005). The wild *M. oleifera* seed oil was found to contain oleic acid up to 73.22%, followed by palmitic, stearic, behenic and arachidic acids 6.45, 5.50, 6.16, and 4.08%, repectively (Anwar & Rashid, 2007). These average values were not so different from those of results of Tsaknis et al. (1999a,b), Tsaknis, Lalas, Gergis, Dourtoglou, and Spiliotis (1998), Lalas and Tsaknis (2002), and Anwar and Rashid (2007).

The tocopherol profile of *M. oleifera* and *M. peregrina* oils consisted of ∝-tocopherol, α-tocotrienol, β-tocopherol, ɤ-tocopherol, P8 and δ-tocopherol (Table 1). The oil extracted with petroleum ether had the highest content of α-tocopherol (12.813 and 6.119 mg/100 g) and ɤ-tocopherol (6.900–0.880) and the lowest of α-tocotrienol (0.0 and 0.154 mg/100 g) and δ-tocopherol (0.891 and 0.0 mg/100 g) for *M. oleifera* and *M. peregrina*, respectively. Lalas and Tsaknis (2002) reported that cold pressed *M. oleifera* var. *peyakulam* oil contained 5.06 mg/kg α-tocopherol, 25.40 ɤ-tocopherol, and 3.55 mg/kg δ-tocopherol. In addition, Tsaknis et al. (1999a,b) established 101.46 mg/kg α-tocopherol, 39.54 mg/kg ɤ-tocopherol, and 75.67 mg/kg δ-tocopherol in cold pressed *M. oleifera* oil. The oil produced with solvent extraction had the highest content of α-tocopherol (12.813 and 6.119 mg/100 g). Most vegetable oils contain α-, β-, and ɤ-tocopherols. Therefore, tocopherols present in *M. oleifera* seed oil were expected to offer some protection during storage and processing (Tsaknis et al. 1999a,b). There were significant differences in tocopherol content of *M. oleifera* and *M. peregrina*. Tocopherol contents (α, ɤ, and δ) of *M. oleifera* oil amounted to 140.5, 63.18, and 61.70 mg/kg, respectively (Anwar & Rashid, 2007). The content of α-tocopherol in Moringa oil is in close agreement with the values reported for soybean, ground nut, and palm oils (Norman, 1979; Rossell, 1991). The concentration of δ-tocopherol was slightly lower than the values reported for *M. oleifera* oil from Kenay (Tsaknis et al. 1999a,b). The δ-tocopherol content (0.0–0.891 mg/100 g) was lower than those of coconut (14.0 mg/kg) and sunflower (34.0 mg/kg) oils (Rossell, 1991). High tocopherol content would be expected to contribute good oxidative stability and protection to the *M. oleifera* oil during storage and processing.

TABLE 2 Sterols and tocopherols contents (%) of *Moringa oleifera* and *peregrina* seed oils

Parameter	*Moringa species*		Mean difference
	oleifera	*peregrina*	
Sterols			
Cholesterol	ND	0.46 ± 0.07	0.46**
Brassicasterol	ND	2.04 ± 0.21	2.04**
Campesterol	3.59 ± 0.04	4.91 ± 0.23	1.32**
Stigmasterol	23.78 ± 0.87	4.69 ± 0.13	19.09**
$\Delta^{5,23}$-Stigmastadienol	ND	1.53 ± 0.08	1.53**
Clerosterol	ND	1.40 ± 0.07	1.40**
Δ^{7}-Campesterol	74.39 ± 0.37	1.97 ± 0.09	72.42**
β-Sitosterol	11.78 ± 0.65	42.23 ± 1.07	30.47**
Sitostanol	ND	1.83 ± 0.06	1.83**
Δ^{5}-Avenasterol	ND	0.48 ± 0.03	0.48**
Δ^{7}-Stigmasterol	16.60 ± 0.75	5.55 ± 0.06	11.05**
Δ^{7}-Avenasterol	ND	2.76 ± 0.24	2.76**
Tocopherols:			
α -tocopherol	12.81 ± 0.61	6.12 ± 0.05	6.69**
α -tocotrienol	0.00 ± 0.00	0.15 ± 0.09	0.15*
β-tocopherol	0.54 ± 0.13	0.00 ± 0.00	0.54**
γ-tocopherol	6.90 ± 0.46	0.88 ± 0.02	6.02**
Plastochromanol-8	1.11 ± 0.02	0.21 ± 0.02	0.90**
δ- tocopherol	0.89 ± 0.07	0.00 ± 0.00	0.89**

Values are means (±SD) of triplicate samples.
**$p \leq .01$.
*$p \leq .05$.
Abbreviation: ND, Not detected.

The sterol composition of the *M. oleifera* and *M. peregrina* oils are shown in Table 2. 7-Campesterol (74.39%) and p-sitosterol (42.23%) appeared to be the most predominant sterol in *M. oleifera* and *M. peregrina*, respectively. While the main sterols of *M. oleifera* oil are 7-campesterol (74.39%), β-sitesterol (11.78%), 7-stigrasterol (5.55%), stigmasterol (4.69%), and campesterol (3.59%), the major sterols of *M. peregrina* determined as β-sitosterol (42.23%), stigmasterol (23.78%), 7-stigmasterol (16.60%), campesterol (4.91%), 7-avenasterol (2.76%), and

TABLE 3 Sugar contents (gm/100 gm) of *Moringa oleifera* and *peregrina* leaves and seed meals

	Leaves			*seed meals*		
Composition	***oleifera***	***peregrina***	**Mean difference**	***oleifera***	***peregrina***	**Mean difference**
Fructose	3.96 ± 0.17	0.31 ± 0.09	3.65**	0.87 ± 0.11	0.39 ± 0.09	0.48**
Glucose	6.65 ± 0.13	1.15 ± 0.01	5.50**	3.67 ± 0.59	3.02 ± 0.41	0.15*
Sucrose	0.011 ± 0.01	0.033 ± 0.00	0.020*	1.67 ± 0.13	2.79 ± 0.95	1.07*
Raffinose	0.011 ± 0.00	0.00 ± 0.00	0.011	0.12 ± 0.03	0.06 ± 0.01	0.06*
Stachyose	0.04 ± 0.10	0.00 ± 0.00	0.040**	0.14 ± 0.02	0.12 ± 0.02	0.02*
Verbascose	0.00 ± 0.00	0.00 ± 0.00	0.00	0.07 ± 0.01	0.03 ± 0.01	0.04**

Values are means (±SD) of triplicate samples.
**$p \leq .01$.
*$p \leq .05$.

brassicasterol (2.04%). Total sterol content, of *M. oleifera* and *M. peregrina* oils were found to be 1,012.89 and 4,203.08 mg/kg, respectively. The sterol fractions of *M. oleifera* seed oil from a wild provenance of Pakistan mainly consisted of β-sitosterol (46.16%), stigmasterol (18.80%), campesterol (17.95%), and Δ^5 avenasterol (9.26%) together with small amounts of clerosterol, 24-methylene cholesterol, Δ^7-campestanol, stigmastanol, and 28-isoavenasterol (Anwar & Rashid, 2007). Lalas and Tsaknis (2002) reported that cold pressed *M. oleifera* oil contained 15.81% campesterol, 23.10% stigma sterol, 45.58% β-sitasterol, and Δ^5-avenasterol. In another study, *M. oleifera* cold pressed oil contained 14.03% campesterol, 17.27% stigmasterol, 49.19% β-sitosterol, and 12.79% Δ^5-avenasterol (Tsaknis et al., 1999a,b). The sterol

TABLE 4 Crude protein and free amino acids profiles (gm/100 gm) of *Moringa oleifera* and p *peregrina* leaves and seed meal

	Leaves			*seed meal*		
Protein/amino acid	***oleifera***	***peregrina***	**Mean difference**	***oleifera***	***peregrina***	**Mean difference**
Crude protein	28.73 ± 0.56	25.97 ± 2.69	2.76**	40.12 ± 1.73	32.09 ± 1.38	8.03**
Taurine	0.105 ± 0.02	0.055 ± 0.01	0.050*	0.147 ± 0.03	0.077 ± 0.01	0.070*
Hydroxyproline	0.100 ± 0.01	0.075 ± 0.01	0.025*	0.140 ± 0.02	0.105 ± 0.01	0.035*
Aspartic Acid	2.185 ± 0.06	0.440 ± 0.17	1.745**	3.059 ± 0.02	0.616 ± 0.24	2.443**
Threonine	1.265 ± 0.13	0.995 ± 0.02	0.270*	1.771 ± 0.19	1.393 ± 0.03	0.378*
Serine	1.060 ± 0.04	0.885 ± 0.04	0.175*	1.484 ± 0.06	1.239 ± 0.05	0.245*
Glumatic Acid	2.660 ± 0.13	0.500 ± 0.08	2.160**	3.724 ± 0.18	0.700 ± 0.12	3.024**
Proline	1.280 ± 0.11	0.510 ± 0.04	0.770**	1.792 ± 0.16	0.714 ± 0.06	1.078*
Glycine	1.450 ± 0.11	0.370 ± 0.07	1.080**	2.030 ± 0.16	0.518 ± 0.10	1.512**
Alanine	1.605 ± 0.33	0.310 ± 0.08	1.295*	2.247 ± 0.46	0.434 ± 0.12	1.813*
Cysteine	0.280 ± 0.04	0.095 ± 0.04	0.185*	0.392 ± 0.06	0.133 ± 0.04	0.259*
Valine	1.345 ± 0.12	0.200 ± 0.04	1.145**	1.883 ± 0.17	0.280 ± 0.06	1.603**
Methionine	0.560 ± 0.08	0.355 ± 0.08	0.205*	0.784 ± 0.12	0.497 ± 0.11	0.287*
Isoleucine	1.155 ± 0.03	0.170 ± 0.03	0.985**	1.617 ± 0.05	0.238 ± 0.04	1.379**
Leucine	2.070 ± 0.15	0.300 ± 0.06	1.770**	2.898 ± 0.22	0.420 ± 0.08	2.478**
Tyrosine	0.915 ± 0.08	0.160 ± 0.01	0.755**	1.281 ± 0.11	0.224 ± 0.02	1.057**
Phenylalanine	1.595 ± 0.06	0.190 ± 0.03	1.405**	2.233 ± 0.09	0.266 ± 0.04	1.967**
Hydroxylysine	0.690 ± 0.04	0.040 ± 0.01	0.650**	0.966 ± 0.06	0.056 ± 0.02	0.910**
Ornithine	0.060 ± 0.01	0.015 ± 0.01	0.045*	0.084 ± 0.02	0.021 ± 0.01	0.063*
Lysine	1.540 ± 0.14	0.185 ± 0.03	1.355**	2.156 ± 0.20	0.259 ± 0.05	1.897**
Histidine	0.730 ± 0.03	0.070 ± 0.01	0.660**	1.022 ± 0.04	0.098 ± 0.02	0.924**
Arginine	1.820 ± 0.06	0.155 ± 0.02	1.665**	2.548 ± 0.08	0.217 ± 0.03	2.331**
Tryptophan	0.510 ± 0.03	0.055 ± 0.02	0.455**	0.714 ± 0.04	0.077 ± 0.03	0.637**

Values are means (±SD) of duplicate samples.
**$p \leq .01$.
*$p \leq .05$.

compositions of the most conventional edible oils are varied from that of the investigated *M. oleifera* oil (Rossell, 1991). Variation in the phytosterol contents among the Moringa species of different regions and varieties have also been observed (Anwar & Rashid, 2007). Present analysis shows the potential of the Moringa oils for edible and industrial use provided it is cultivated on a large scale.

Moisture, protein, and sugar contents of leaves and seed cakesof *M. peregrina* and *M. oleifera* are given in Table 3. While moisture contents of both leaves is found similar, their protein contents were found at significant level. Protein contents of *M. peregrina* and *M. oleifera* changed between 4.36 and 23.83%, respectively. Moisture contents of seed cakes of plants were found partly low. *M. peregrina* and *M. oleifera* seed cakes contained 21.44 and 26.81%, respectively. Abiodun, Adegbite, and Omolola, (2012) reported that *Moringa* flour and *Moringa* seed cake flour contained 4.70 and 5.03% moisture and 28.04 and 50.80% crude protein, respectively. The high protein content of these flour samples give an indication of their usefulness in human diet and as lives tock feed (Abiodun et al. 2012). Leaves and meal (fat-free kernels) of *M. oleifera* contained 264 and 614 g/kg crude protein, respectively (Abbas, 2013). In previous study, raw *M. oleifera* flour contained 10.60 mg/100 g moisture and 18.86 mg/100 g crude protein (Ijarotimi, Adeoti, & Ariyo, 2013). *Moringa oleifera* leave meals contained 6.37% moisture and 22.23% crude protein (Aye & Adegun, 2013). Madukwe, Ezeugwa, and Eme (2013) reported that *M. oleifera* contained 0.66% protein. Generally, crude protein contents of *Moringa* seeds changed betwenn 18.63 and 35.37% (Anwar & Rashid, 2007; Compaore et al. 2011; Kawo et al. 2009). In another study, leaves of *Moringa stenopetala* and *M. oleifera* contained 26.6 and 28.9% crude protein, respectively (Melesse, 2011). Sugar profile of leaves and seed cokes of *M. peregrina* and *M. oleifera* are presented in Table 3. Glucose contents of all samples were found high. Glucose contents of samples ranged from 1.05% (M. *peregrina* leave) to 6.10% (*M.oleifera* leave). *Moringa peregrina* and *M. oleifera* contained 3.37 and 2.77% glucose, respectively. Raffinose, stachyose, and verbacose were not detected in leaves of *M. peregrina*. Fructose contents of samples changed between 0.28% (*M. peregrina* leave) to 3.63% (*M. oleifera* leaves). Compaore et al. (2011) reported that *M. oleifera* pulp contained 2.57 g/100 g (dw) glucose, 0.03 g/100 g (dw) fructose, and 2.91 g/100 g (dw) sucrose. Our glucose and fructose results are found partly higher than that of results of Compaore et al. (2011). Differences between results can be explained by geographical difference in soil composition characterized by abundont rains and vegetation.

The concentration of amino acids in leaves and seed cakes of *M. peregrina* and *oleifera* has been presented in Table 4. Most of the essential amino acids in *M. oleifera* are slightly lower than those reported by Makkar and Becker (1996) for leaves of the same Moringa species. Overall mean concentrations of arginine, cysteine, isoleucine, leucine, lysine, methionine, phenylalanine, threonine, and valine in leaves of *M. stenopetala* and *M.oleifera* (g/kg, dw) had been determined as 14.3, 3.73, 10.1, 20.0, 12.7, 3.94, 15.1, 12.2, and 13.0, respectively. The concentrations of leucine, lysine, arginine reported by Booth and Wickens (1988) and Melesse (2011) for *M.oleifera* leaves are comparable with the current findings. These variations might be possibly attributed to age of the tree, agro-climatic conditions, altitude, variety, harvest time, and soil type. Generally, amino acid contents of *M. oleifera* leave and cakes were found partly higher than those of amino acid results of *M. peregrina* leave and cakes. Glutemic acid and arginine contents of *M. peregrina* and *M. oleifera* cakes changed between 3.43 and 3.70% and 2.21 and 2.99%, respectively. Total amino acid contents of Moringa seed samples ranged from 2.84% (*M. peregrina* leave) to 20.08% (*M. oleifera* leave).

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CONFLICT OF INTEREST

The authors declared that they have no conflict of interest.

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