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Research Article
Fatty acids and Macroelements of *Moringa* (*M. peregrina* and *M. oleifera*) Seed Oils

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Abstract

Background and Objective: Recent years have shown increased interest in cultivating *Moringa* and producing its oil in Saudi Arabia. This study aimed to determine the fatty acids and macroelements in oils from two species of *Moringa* [*M. peregrina* (MP) and *M. oleifera* (MO)] seeds. **Methodology:** MP oils were extracted using solvent- and pressing-based methods and MO oils were extracted using a solvent-based method. The fatty acid composition and macroelement contents in the oil samples were determined through gas chromatography (GC) and inductively coupled plasma-mass spectrometry (ICP-MS), respectively. **Results:** The approximate chemical composition of *Moringa* seeds showed that the MP seeds exhibited a higher oil content (49.19%) than the MO seeds (33.69%), whereas the MO seeds had significantly higher contents of protein (37.78%), fiber (5.10%) and ash (3.69%) than the MP seeds (27.67, 4.86 and 2.56%, respectively). The dominant fatty acids in *Moringa* oils were saturated palmitic acid and monounsaturated oleic acid, which were present in content ranges of 8.99-78.05% and 9.86-77.33% in the solvent- and press-extracted MP oils, respectively. These amounts were considered significantly higher than the amounts found in solvent-extracted MO oil (6.18-74.87%), which has significantly higher potassium and magnesium contents (36.67 and 5.86 ppm) than solvent-extracted MP oil (9.07 and 0.95 ppm) and the determined macroelements were found at undetectable levels in the press-extracted MP oils. **Conclusion:** This study spotlights the possibility of producing edible oil from local *Moringa* seeds that contains a high monounsaturated fatty acid (oleic acid) content and satisfactory concentrations of potassium and magnesium and can thus be used in different applications.

Key words: Moringa peregrina seed oil, *Moringa oleifera* seed oil, fatty acid composition, macroelements, pressing- and solvent-based extraction, ben oil, behen oil

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Competing Interest: The author has declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Moringa seeds belong to the Moringaceae family, which has 10-14 species that are grown in tropical and non-tropical regions and *Moringa peregrina* (*MP*) and *Moringa oleifera* (MO) are the most common species[1,2]. *Moringa peregrina* (MP) is naturally distributed in southwest region of Saudi Arabia, whereas *Moringa oleifera* (MO) spread to this region through cultivation[3]. The English name of this species is drumstick, horseradish and benzoil tree and this species is also called Elyasar in the Arabic region[4-6]. *Moringa* seeds contain various oil protein and oil amounts and these amounts show differences among the categories of *Moringa* species[3,7]. The resulting oil, which is known as ben oil or behen oil, has a fine aroma and a pale-yellow color and is odorless[8]. As a result, *Moringa* oil has been used for edible and cosmetic purposes[9,10].

From a nutritional aspect, the high levels of oleic acid in edible oil are linked to a reduced risk of heart disease due to its effect on serum cholesterol and lipids[6] and the presence of some elements that exert a positive impact on the nutritional status[11].

Several researchers have investigated the fatty acid composition of *MO* oil and found that oleic acid was its predominant fatty acid, with an average content of 76% and the dominant saturated acids are palmitic and behenic acids[12-14]. However, *MP* oil has not been extensively evaluated. Recent efforts have attempted to expand the cultivation of the *Moringa* tree and produce useful oil from Moringa seeds that could have consumption and economic benefits in Saudi Arabia. This study aimed to determine the fatty acid composition and macroelement contents of solvent-extracted *MP* (SEMP) oil, solvent-extracted MP (SEMO) oil and pressing-extracted MP (PEMP) oil. The fatty acids of the oils were analyzed by gas chromatography (GC) and ICP-MS was used to determine the macroelement contents.

MATERIALS AND METHODS

Materials: The MP and MO seeds used in this study were grown in Saudi Arabia and collected in 2016. The MO seeds were generously donated by the Cooperative Society of Moringa And Desert Plants, whereas the MP seeds were purchased. Only undamaged seeds were selected, cleaned, dehulled, ground into fine powder and stored under cool-dry storage conditions before extraction and experimentation. All the solvents and reagents used in the analytical determinations were obtained from Sigma-Aldrich (USA).

Methods

Approximate chemical composition of Moringa seeds: For the chemical analysis, the crude protein (micro-Kjeldahl), fat/oil, crude fiber and ash contents of *Moringa* seeds were determined according to a previously described method[15].

Extraction of the oils: Mechanical pressing and solvent-based methods were used to extract the oil of MP seeds and *MO* oil was extracted using a solvent-based method. Hexane solvent was used to extract the oils according to a previously described method[16].

Gas chromatography analysis of Moringa oil: According to a previously described method[17], the fatty acid composition of *Moringa* seed oils was determined by gas chromatography (GC). The oil was converted to fatty acid methyl esters (FAMEs) and a 0.2 mL sample volume of the FAME solution was injected into a GC instrument (Agilent Technologies, USA) equipped with a flame-ionization detector and a polar capillary column (Supelco SP-2560, 100 m length×0.25 mm internal diameter and 0.20 μm film thickness). The operating temperature program was set initially to 100°C increased to 204°C and then maintained at 240°C for 16 min. The detector temperatures were set to 300°C and helium was used as the carrier gas at a flow rate of 31 mL min^{-1}. The FAME peak was identified by comparing its retention time with that of reference standards. The fatty acid compositions are reported as relative percentages calculated as the ratio of the peak area of each fatty acid to the total peak area of all the fatty acids in the oil samples.

Determination of the macroelements of Moringa oils: *Moringa* oil extracted from MP and MO seeds was prepared for macroelement analysis [potassium (K), sodium (Na) and magnesium (Mg)] using a microwave digestion oven (Discover SP-D, SPD80, Germany) equipped with an Explorer autosampler. The oil samples were dissolved in nitric acid (HNO_3), hydrogen peroxide (H_2O_2) and hydrochloric acid (HCl) and then diluted with Milli-Q water. The samples were injected into an inductively coupled plasma mass spectrometer (ICP-MS, Japan) equipped with a collision cell (Agilent 7700x). The operating conditions were set based on the instructions

provided in the manual and the instrument was calibrated following the instructions provided with the IPC-MS instrument.

Statistical analysis: The results are expressed as the Means±standard deviations. The experimental data were analyzed by a t-test and one-way ANOVA (Duncan's multiple range test) using SPSS Version 17.0 software (USA). Significant differences between the values were defined at $p \leq 0.05$.

RESULTS

Approximate chemical composition of Moringa seeds: Table 1 depicts the approximate chemical composition of MP and MO seeds and the mean values of the protein, oil, ash and fiber contents of *Moringa* seeds are presented. In general, MO seeds were slightly richer in nutrients than the MP seeds; however, the oil content was higher (49.19%) in MP than MO seeds (33.69%). Oil and protein were the main components of the seeds of the two *Moringa* species: the protein content ranged from 27.67-37.78% in the MP and MO seeds, whereas the fiber and ash contents of these seeds ranged from 4.86-2.56% and from 5.10-3.69%, respectively. In addition, a significant difference ($p \leq 0.05$) for all presented parameters was found between the two seeds (Fig. 1 and 2).

Fatty acid composition: Table 2 shows the fatty acid composition of *Moringa* seed oils (SEMP, SEMO and PEMP). As shown, the USFAs in *Moringa* seed oil accounted for more than 80% of the oil. In addition, the monounsaturated fatty acid (MUSFA) contents were higher in SEMP and PEMP oils compared with SEMO oil and small amounts of polyunsaturated fatty acids (PUSFAs) were found in the oil samples.

The palmitic acid (C16:0) content was significantly higher in SEMP and PEMP oils than in SEMO oil; specifically, the content of palmitic acid in SEMP, SEMO and PEMP oils was 8.99, 6.18 and 9.86%, respectively. In addition, behenic acid (C22:0) and arachidic acid (C20:0) were found in notably higher amounts (5.43, 2.69%) in SEMO oil compared with SEMP oil (2.37, 1.98%) and PEMP oil (2.18, 1.72%). The stearic acid (C18:0) content ranged from 3.92-4.19, with no significant differences ($p \leq 0.05$) between all types of *Moringa* oils.

The analysis of USFAs revealed that the palmitoleic acid (C:16:1) content was significantly higher in PEMP oil (2.12%) than in SEMP (1.53%) and SEMO (1.31%) oils. The content of oleic acid (C18:1) was significantly lower (74.87%) in SEMO oil compared with PEMP and SEMP oils (77.33 and 78.05%, respectively). The very low content of linoleic acid (C:18:2) in *Moringa* oils ranged from 0.42-0.68%, with no significant differences ($p \leq 0.05$).

Fig. 1: *Moringa peregrina* seeds

Fig. 2: *Moringa oleifera* seeds

Table 1: Proximate composition (%) of *Moringa* seeds

Moringa seeds	Protein**	Fat/oils	Ash	Fiber
MP	27.67±0.86^a	49.19±0.68^a	2.56±0.02^a	4.86±0.02^a
MO	37.78±0.20^b	33.69±0.05^b	3.69±0.11^b	5.10±0.02^b

MP: *Moringa peregrina* seeds, MO: *Moringa oleifera* seeds, *Mean±standard deviations, Means in the same column with different superscript letters are significantly different ($p \leq 0.05$), **Protein = N (%)×6.25

Table 2: Fatty acid composition (%) of *Moringa* seed oils

Oil samples	(C16:0)	(C18:0)	(C16:1)	(C18:1)	(C18:2)	(C20:0)	(C22:0)	SFA	USFA	MUSFA	PUSFA
SEMP	8.99±0.47*[a]	4.19±0.04	1.53±0.02[a]	78.05±0.38[a]	0.42±0.08[a]	1.98±0.06[a]	2.37±0.13[a]	18.06±0.16	81.94±0.16	81.16±0.46	0.42±0.08
SEMO	6.18±0.05[b]	4.01±0.07	1.31±0.08[b]	74.87±1.54[b]	0.68±0.00[b]	2.69±0.06[b]	5.43±0.29[b]	19.77±0.53	80.24±0.53	78.37±1.70	1.48±0.79
PEMP	9.86±0.70[a]	3.92±0.43	2.12±0.03[c]	77.33±1.22[a]	0.47±0.00[a]	1.72±0.02[c]	2.18±0.06[a]	18.47±1.29	81.53±1.29	80.93±1.36	0.60±0.07

SEMP: solvent-extracted *Moringa peregrina* seed oil, SEMO: solvent-extracted *Moringa oleifera* seed oil, PEMP: pressing-extracted MP, *Mean±standard deviations, Means in the same column with different superscript letters are significantly different ($p \leq 0.05$), SFA: Saturated fatty acid, USFA: Unsaturated fatty acid, MUSFA: Monounsaturated fatty acid, PUSFA: Polyunsaturated fatty acid

Macroelement contents: Table 3 shows the macroelement concentrations (in ppm) of potassium (K), sodium (Na) and magnesium (Mg) in *Moringa* oils (SEMP, SEMO and PEMP). The results indicated that K and Mg were found in both SEMP and SEMO oils. Clearly, the SEMO oil exhibited significantly higher K and Mg concentrations (36.67 and 5.86, respectively) than SEMP oil (9.07 and 0.95, respectively). However, a trace amount of Na was observed only in SEMP (0.32), whereas this macroelement was not detected in the PEMP oil sample.

DISCUSSION

The study results presented in Table 1 indicate that the protein, fiber and mineral contents of M*O* (37.78, 5.10 and 3.69%, respectively) were significantly higher than those in MP seeds (27.67, 4.86 and 2.56%, respectively). *Moringa* seeds are considered good sources of both protein, which helps repair body tissues and fiber, which prevents heart disease, cancer and diabetes. These results agree with those of previous studies[3,12,18], which found that *Moringa* seeds are rich in nutrients, specifically protein, oil, fiber and minerals. The differential contents among the seed species could be attributed to genetic variations or different environmental conditions. Additionally, the oil contents in MO and MP seeds ranged from 33.69-49.19%. The oil in *Moringa* seeds, which is found in markedly high amounts, can be utilized as a substitute source of vegetable oils, such as olive oil. The high percentage of oil in *Moringa* seeds agrees with that found in previous studies[7,14], which reported that the oil content of MP seeds ranged from 49.8-57.25%, whereas the oil content in MO seeds is approximately ranged from 38-40%[19]. The *Moringa* oil content is influenced by the genetic variation of the seeds, the environmental and climate conditions and the cultivation and extraction methods.

The results presented in Table 2 show that the USFA content in *Moringa* seed oil (more than 80%) is higher than the SFA content (18.47%). The higher content of USFAs and lower amount of SFAs in edible oil are desirable. The dominant saturated fatty acid was identified as palmitic acid (C16:0), which was found at percentages of 8.99, 6.18 and 9.86% in SEMP, SEMO and PEMP oils, respectively. These results agree with those of previous studies[7,14] that identified palmitic and behenic as the dominant saturated acids in *Moringa* oil (both at percentages up to 6.4%). The prominent fatty acid in *Moringa* oil was oleic acid, which was found between 74.87 and 78.05%. The results agree with those obtained in previous studies,[8,12,13,20] which reported that the oleic acid content in *Moringa* seed oils ranged from 68-73.5%. Oleic acid is related to the high stability of oil in terms of oxidative rancidity and

Table 3: Macro element contents of *Moringa* seed oils

Oil samples	Potassium (ppm)	Sodium (ppm)	Magnesium (ppm)
SEMP	9.07±4.01*[b]	0.32±0.04	0.95±0.08[b]
SEMO	36.76±0.45[a]	ND**	5.86±0.32[a]
PEMP	ND	ND	ND

SEMP: Solvent-extracted *Moringa peregrina* seed oil, SEMO: Solvent-extracted *Moringa oleifera* seed oil, PEMP: Pressing-extracted MP, *Mean±standard deviations, **ND: Not detectable, the detection limits for potassium, sodium and magnesium were 0.02, 0.04 and 0.04, respectively

decreases in the risk of coronary heart disease caused by high cholesterol levels in the serum[6,14,21,22]. In addition, the variations in the fatty acid content might be due to the different species, agricultural factors and the extraction methods used[12,20].

As shown in Table 3, significantly higher concentrations of K and Mg (36.67 and 5.86, respectively) were found in the SEMO oil than in SEMP oil (9.07 and 0.95, respectively) and trace amounts of Na were observed only in SEMP (0.32). These elements are essential for the body: Potassium works with sodium to control the blood pressure and maintain the fluid and electrolyte balance and cell integrity and Magnesium is necessary for energy metabolism[23]. Therefore, the presence of an element in edible oil might be related to environmental factors, such as the soil content[11].

The monounsaturated fatty acid, potassium and magnesium contents in *Moringa* oil are considered desirable components in edible oil. Therefore, studying the properties of *Moringa* oil and its food and health applications would be of interest.

CONCLUSION

The fatty acid compositions and macroelement contents of SEMP, SEMO and PEMP oils were analyzed and the results showed that *Moringa peregrina* seeds contained higher amounts of oil than *Moringa oleifera* seeds. These seeds are considered rich sources of protein, fiber and ash. The monounsaturated fatty acid (oleic acid) content was higher in the *Moringa peregrina* oil samples than *Moringa oleifera* oil. In contrast, the potassium and magnesium concentrations were higher in *Moringa oleifera* oil.

SIGNIFICANCE STATEMENT

This study discovers the potential of producing local *Moringa* oil as a new source of edible oil with a high content of oleic acid and satisfactory macroelement concentrations that could be beneficial for human nutrition. This study will help researchers uncover the critical food and health applications of *Moringa* oil. Thus, new information regarding its micronutrient and oil properties can be determined.

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