



Proceeding Paper

Production System Influences on the Quality of *Moringa oleifera* Seed Oil: A Nutritional and Functional Analysis [†]

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Abstract

Moringa oleifera is a plant species well known for its high nutritional and functional value, whose seeds are a source of oil rich in Unsaturated Fatty Acids (UFAs), especially oleic acid. The quality of this oil can be influenced by agroecological conditions and the production system. Currently, there is little information about the nutritional profile of this species of seeds harvested in Paraguay, and therefore, its use among the regional population is limited. The objective of this present study was to compare the fatty acid profile and nutritional indices of *Moringa oleifera* seed oil from an organic crop and backyard agriculture. Analysis was performed using gas chromatography, and indicators such as the UFA/SFA (Saturated Fatty Acid) ratio, oxidisability index (OI), oxidative stability (OS), atherogenic index (AI), thrombogenic index (TI), and unsaturation index (DBI) were calculated. Differences between groups were analysed using Student's *t*-test ($p < 0.05$). The results revealed statistically significant differences between the evaluated samples. The oil from backyard agriculture seeds presented a lower proportion of SFA (20.62% vs. 22.64%), with marked differences in palmitic (C16:0), stearic (C18:0), and arachidic (C20:0) acid contents. In contrast, it showed a higher content of UFA (77.21%), including a significantly higher content of oleic acid (74.77%) and eicosanoic (C20:1) and linoleic acids (C18:2). Higher values of the UFA/SFA ratio (3.74), OS (119.25) and DBI (78.17) were also observed in these samples. Furthermore, the AI was lower in the oil from backyard agriculture seeds (0.13), reinforcing its heart-healthy profile. In conclusion, the seeds used in backyard agriculture produced an oil with a healthier and more stable lipid composition. These characteristics mean that *Moringa oleifera* seed oil from backyard agriculture can contribute to food and nutritional security in family farming, with a focus on preventing cardiovascular disease.

Keywords: *Moringa oleifera*; seed oil; fatty acid profile; nutritional quality; organic crop



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1. Introduction

Moringa oleifera is a fast-growing tree with soft wood that belongs to the Moringaceae family. It is native to the sub-Himalayan regions of northern India. Thanks to its ability to adapt to different climates, including droughts, it has spread to other areas, including tropical and subtropical regions such as Paraguay [1]. In recent years, moringa seeds have

been studied as a source of fatty acids due to their oil content of 35–45% *w/w*, with oleic acid accounting for more than 70% of this [2].

Conversely, several nutritional indices in oils have recently been studied, including the ratio of unsaturated to saturated fatty acids (UFA/SFA), the thrombogenic index (TI) and the atherogenic index (AI), as well as oxidative susceptibility (OS) and calculated oxidability (Cox). Evaluating the AI and TI indices can provide information on the potential health effects of individual fatty acids, particularly with regard to the risk of atherosclerosis, blood clot formation, atheroma and thrombus formation [3]. Conversely, OS and Cox predict the propensity for peroxidation based on the proportion of mono- and polyunsaturated fatty acids (especially C18:2 and C18:3), which are the most reactive [3,4].

The stress that plants experience in monoculture can cause variations in their fatty acid composition. This study aimed to compare the fatty acid profile and nutritional indices of *Moringa oleifera* seed oil produced using organic farming methods and backyard agriculture.

2. Materials and Methods

Mature pods of *M. oleifera* were harvested from two sampling locations in Paraguay: (a) an organic crop in the city of Piribebuy, Cordillera Department, and (b) a backyard crop in the city of Itauguá, Central Department. The seeds were manually separated and dried at 40 °C.

The oil was obtained from freeze-dried seeds that were cold pressed (CDR Food Lab, Italy). The oil extraction yield was 17%, from 100 g of seeds. Fatty acid esterification was then performed according to the AOCS Ce 2-66 method [5], and the sample was injected into a GC-FID (HP 6890 Series, USA). The injection was split at a ratio of 20:1, with a volume of 1 µL, using a Stabilwax column (30 m × 0.32 mm). Helium was used as the carrier gas and hydrogen as the auxiliary gas. The inlet and detector temperatures were 240 °C and 400 °C, respectively. The temperature programme started at 60 °C, increased to 180 °C at 10 °C/min (with a 5 min hold), then rose to 215 °C at 5 °C/min and finally reached 240 °C at 5 °C/min, with a 16 min hold. These parameters were established in the Ce 1 j-07 method [5].

The results are expressed as a percentage of abundance. Nutritional indices were calculated as detailed by Belhoussaine et al. [3]. Significant differences were determined by using Student's *t*-test ($p \geq 0.05$) and RStudio version 2024.09.0+375.

3. Results and Discussion

The results of the fatty acid profile analysis are shown in Table 1. A total of 10 fatty acids were found in both samples. Oleic acid (18:1) was the most abundant, at 73.98% and 74.77% for the organic (M1) and backyard agriculture (M2) samples, respectively. No statistically significant differences were observed between the analysed oils (Student's *t*-test, $p < 0.05$). However, significant differences were observed in the content of other fatty acids, such as palmitic acid (C16:0), stearic acid (C18:0), arachidic acid (C20:0), eicosanoic acid (C20:1) and linoleic acid (C20:2). The sum of SFAs was higher in organic crops (22.64%), while MUFAs were higher in backyard agriculture samples (76.26%). This could be explained mainly by differences in agricultural management and water stress during seed filling. *Moringa* crops in Piribebuy (M1) are grown in more degraded soils where sugarcane was previously cultivated, and they benefit from fertilisation and irrigation systems, as well as having lower genetic diversity. Under conditions of fluctuating water and nutrition, which increase the abiotic stress of backyard crops, there may be greater activity or expression of desaturase enzymes (which convert SFAs to MUFAs), resulting in a higher relative percentage of SFAs [6]. Ensslin et al. [7] found that ex situ cultivation alters functional traits

and responses to drought. This supports the idea that agricultural management can reduce resilience and change metabolic pathways related to lipid composition [7].

Table 1. Fatty acid profile of *M. oleifera* seed oil grown in organic crops (M1) and backyard agriculture (M2).

Acid	Formula	M1 (Organic Crop)	M2 (Backyard Agriculture)
Miristic	C14:0	0.09 ± 0.04 ^a	0.11 ± 0.00 ^a
Palmitic	C16:0	5.56 ± 0.05 ^a	5.37 ± 0.08 ^b
Stearic	C18:0	6.24 ± 0.01 ^a	5.14 ± 0.04 ^b
Arachidic	C20:0	3.73 ± 0.08 ^a	3.22 ± 0.04 ^b
Lignoceric	C24:0	0.96 ± 0.07 ^a	0.93 ± 0.02 ^a
Behenic	C22:0	6.1 ± 0.1 ^a	6.1 ± 0.1 ^a
SFA		22.6 ± 0.2 ^a	20.6 ± 0.4 ^b
Palmitoleic	C16:1	1.3 ± 0.1 ^a	1.49 ± 0.01 ^a
Eicosenoic	C20:1 11 c	1.76 ± 0.08 ^a	2.16 ± 0.06 ^b
Oleic	C18:1	73.9 ± 0.4 ^a	74.8 ± 0.3 ^a
UFA		75.8 ± 0.3 ^a	77.2 ± 0.3 ^b
MUFA		75.2 ± 0.3 ^a	76.2 ± 0.3 ^b
Linoleic	C18:2	0.54 ± 0.03 ^a	0.96 ± 0.06 ^b
PUFA		0.54 ± 0.03 ^a	0.96 ± 0.06 ^b
DBI		76.3 ± 0.3 ^a	78.2 ± 0.3 ^b

Different letters indicate that there are significant differences (*t*-test, *p* < 0.05).

It has been reported that there are variations in the lipid composition of moringa seeds, with a lower percentage of oleic acid found in seeds grown in Tunia (73.3%) [1] or the Argentine Chaco (72.32–73.00%) [2].

To evaluate the nutritional quality of the analysed oils, various nutritional indices (UFA/SFA, IA, IT, CoX and OS) were calculated, and significant differences were observed in all of them (Table 2). The UFA/SFA ratio was higher in oil from backyard farming seeds (3.74) than in oil from organic farming seeds (3.35). A higher ratio has a more positive effect on cardiovascular health [3]. Conversely, lower AI and TI indices were observed in oils from backyard seeds (M2). Lower AI and TI indices indicate a lower risk of atherogenicity and thrombogenicity [3].

Table 2. Nutritional indices of oil from *M. oleifera* seeds.

Index	M1 (Organic Crop)	M2 (Backyard Agriculture)
UFA/SFA	3.35 ± 0.04 ^a	3.74 ± 0.08 ^b
AI	0.15 ± 0.00 ^a	0.13 ± 0.00 ^b
TI	0.28 ± 0.00 ^a	0.31 ± 0.00 ^b
Cox	7951 ± 37 ^a	8460 ± 71 ^b
OS	99.4 ± 1.0 ^a	119 ± 3 ^b

Different letters indicate significant differences (Student's *t*-test, *p* < 0.05). UFA/SFA: thrombogenic index (TI); atherogenic index (AI); oxidative susceptibility (OS); and calculated oxidability (Cox).

Additionally, the calculated oxidability (COX) and oxidative susceptibility (OS) indices were significantly higher in backyard farming than in organic farming. The higher unsaturation in backyard samples (M2) also explains the higher COX and OS values. The greater the proportion of polyunsaturated fatty acids, the greater the theoretical susceptibility to peroxidation, which indicates lower stability against oxidation in the absence of compensatory antioxidants [3].

4. Conclusions

These findings suggest that backyard seeds could provide a healthier lipid profile for food or nutraceutical products. However, their oil or extract would require stabilisation strategies to counteract their greater susceptibility to oxidation. *Moringa oleifera* seed oil produced through domestic agriculture can contribute to food and nutritional security in family farming and for self-consumption, particularly in the prevention of cardiovascular disease.

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