

Compositional and Antioxidant Characterization of *Moringa oleifera* Seed Oil and Press Cake Produced by Mechanical Pressing in Senegal

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Abstract

This study aimed to characterize virgin *Moringa oleifera* seed oil (MOSO) and press cake, produced in Senegal using a traditional cold-pressing method widely employed by local producers. Following harvesting, dehulling, steaming, pressing, decanting, and filtration, the oil extraction yield reached 32.23%. The nutritional, mineral, lipid, and phytochemical compositions, as well as the antioxidant potential of MOSO and residual press cake (MOOC), were evaluated. The seeds exhibited a protein content of 7.74 g/100g and were rich in minerals, particularly phosphorus, potassium, and calcium. Phytochemical analyses revealed the presence of polyphenols, flavonoids, and condensed tannins in both the seeds and the residual press cake. MOOC exhibited the highest levels of total phenolic compounds (2.65 ± 0.04 mg GAE/g DM) and condensed tannins (0.050 ± 0.006 mg CE/g DM), as well as the highest antioxidant capacity, as determined by the FRAP assay (17.38 ± 0.88 mg AAE/g DM). The fatty acid profile was dominated by oleic acid (69.56%), stearic acid (7.19%) and palmitic acid (5.54%), respectively. In summary, MOSO and MOOC contains good physico-chemical properties, including fatty acid composition and antioxidant potential which could prove beneficial for their applications and uses in Senegal.

Keywords

Senegal, *Moringa oleifera*, Mechanical Pressing, Characterization, Bioactive Compounds, Antioxidant Potential

1. Introduction

Moringa oleifera Lam is a highly valued plant species renowned for its substantial nutritional and medicinal properties, attributed to its rich phytochemical composition [1]. The use of *M. oleifera* plant has been extensively studied throughout several domains of functional food and medicine, due to its low toxicity with minimum side effects [2]. *M. oleifera* represents a traditionally important food commodity as the leaves, flowers, fruits and roots of this three are locally used as vegetables [3].

M. oleifera seeds oil (MOSO), known as Ben oil, is particularly prized for its high oleic acid content and antioxidant properties, making it highly promising for the food, pharmaceutical, and cosmetic industries [4]-[6]. Furthermore, the seeds are recognized for containing high oil concentrations, characterized by a significant proportion of polyunsaturated fatty acids that assist in regulating blood cholesterol levels [7]. Additionally, the high oxidative stability of this lipid profile renders the oil particularly suitable for both culinary applications and as a sustainable alternative in industrial formulations [8] [9].

Some extraction methods of these vegetable oils have been developed including conventional techniques, such as cold pressing, solid-liquid extractions (maceration, Bligh-Dyer and Soxhlet extraction) [10] and non-conventional methods like ultrasonic assisted extraction (UAE) assisted by experimental designs [11], microwave-assisted extraction (MAE) [12], and supercritical CO₂ extraction assisted by response surface methodology [13].

In Senegal, cold pressing method, more affordable and easy accessible, is widely used by cooperatives and small-scale producers. It better preserves the oil's heat-sensitive compounds and natural bioactive profile, compared to heat-based extraction processes [1] [14]. Additionally, the *M. oleifera* residual oil cake (MOOC) obtained after extraction is a protein and mineral-rich co-product that can be utilized in human or animal nutrition, thereby minimizing waste and optimizing the total economic utility of the crop [15] [16]. Furthermore, MOSO production by women's groups is common in this country and fosters the financial empowerment of rural households. The cultivation and processing of *M. oleifera*, known locally as "nebeday" rely primarily on social and solidarity economy organizations. This versatility underlines the strategic importance of this crop in Sahelian agricultural economies, where the transition from subsistence cultivation to small-scale industrial processing bolsters resilience against food insecurity and poverty [17]. To combat malnutrition, which affects 22.7% of children under the age of five, Senegalese authorities have established early childhood centers (Cases des tout-petits) offering affordable local dishes prepared using underutilized and sustainable plant derived-oils, such as MOSO [18].

To the best of our knowledge, research on the exploration of physico-chemical properties of MOSO obtained by the technique of cold pressing used by Senegal's farmers remains limited. To date, very few studies have focused on the comprehensive characterization of cold-pressed oil extracted from *M. oleifera* seeds orig-

inating from Senegal.

Therefore, this study highlighted the characterization of MOSO obtained by cold pressing, from Senegal, through determining some parameters related to edible oils, such as the physico-chemical properties, antioxidant potential and fatty acid compositions. The results could provide baseline data for the standardization of the Senegalese MOSO variety for edible as well as other farmers and cooperatives.

2. Research Methods and Materials

The plant material (*Moringa oleifera* seeds) used in this study was obtained from seven (7) trees grown in Ndoffane, in the Kaolack region of Senegal (**Figure 1**). The seeds were harvested from trees belonging to groups working directly with this species. The trees were grown on private land, and permission to harvest the seeds was granted by the plot owners. The Kaolack region is situated between 14°30' and 16°30' West longitude and between 13°30' and 14°30' North latitude. Average annual rainfall ranges from 800 to 900 mm, and the region's terrain is generally flat. The hydrographic network comprises surface waters including the Saloum River and two tributaries of the Gambia River (the Baobolong and the Miniminyang Bolong) as well as groundwater [19]. The samples were identified and authenticated by Assane Goudiaby at the Dakar Herbarium (FST-UCAD) of Cheikh Anta Diop University, Dakar.

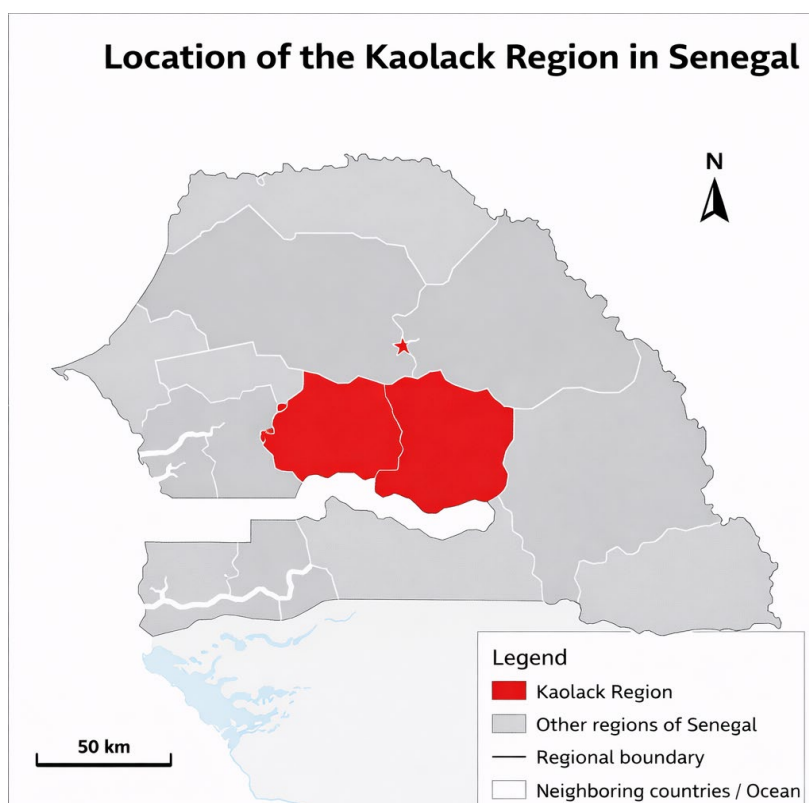


Figure 1. Geographical location of the Kaolack region in Senegal.

2.1. Experiment Plan

2.1.1. Sample Preparation

Mature *M. oleifera* pods were harvested based on their external appearance specifically, their brown color and dry texture (**Figure 2**). The seeds inside were encased in a thin, hard shell that could be removed by hand. Once the shells were removed, the seeds were stored at 4°C, protected from light and moisture, to minimize oxidation, hydrolysis, and other forms of lipid degradation. As moringa branches are fragile, climbing the tree is not recommended [20].



Figure 2. Harvesting (a) and peeling (b) ripe *Moringa oleifera* pods (photos taken on 09/03/2025).

The production of moringa seed oil, from the harvesting of the pods, involves several steps, described in the different **Figures 3-6**. **Figure 2** showed the harvested pods.

Step 1: initial sorting. A manual sorting is carried out to eliminate any pods that show alterations or mold on the surface due to poor harvest conditions.

Step 2: peeling. The peeling is done manually. *Moringa* seeds have a brown pod that is easily removed by hand after a week of drying.

Step 3: hulling. This operation is carried out using a handcrafted machine that separates the seeds from their husks. The device used is easy to operate and can process a variety of seeds, including *Moringa seeds* (**Figure 3**).

Step 4: second sorting. A second sorting is carried out to eliminate all kinds of contaminated hulled seeds (microorganisms, worms).

Step 5: Steaming and pressing. After a week of drying at room temperature, the moringa seeds are steam-heated to approximately 50°C before being pressed.

This steam cooking method allows for better extraction of moringa seeds and increases the oil extraction yield.

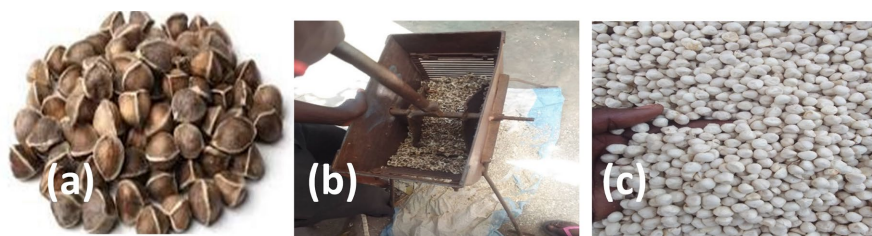


Figure 3. Unhulled seeds (a), the peeling machine (b) and hulled seeds (c).

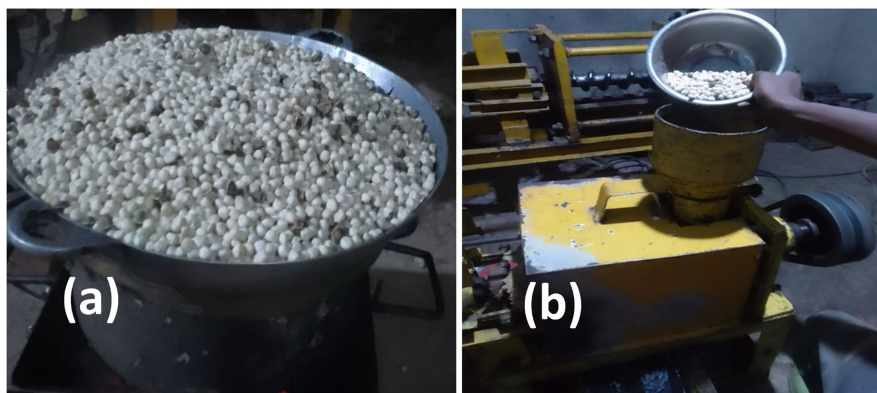


Figure 4. Steaming (a) and cold pressing (b).



Figure 5. The extraction machine (a), the Moringa oil before filtration (b) and the press cakes.

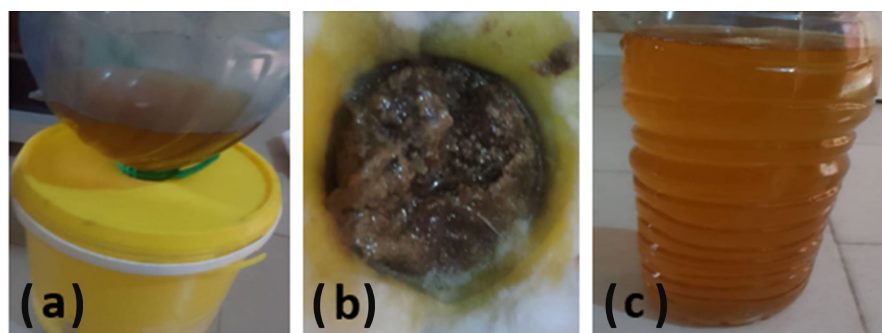


Figure 6. Filtration process.

2.1.2. Oil Extraction

This work delves into the biotechnological advancements in harvesting pods, efficient hulling, and cold extraction techniques for *MOSO*, emphasizing sustainable and high-quality production. The biotechnological potential of *M. oleifera* extends beyond its oil, as it uniquely enhances plant growth and stress tolerance through metabolic and lipid alterations, differentiating it from other biotech crops [21].

The study investigates a twin-screw extrusion system, for the mechanical cold extraction of oil from *M. oleifera* seeds, focusing on optimizing process parameters to maximize oil yield and quality. In principle, traditional processing meth-

ods, often used by farmers and cooperatives in Senegal, rely on simple, almost entirely manual techniques. Mechanical extraction, particularly via cold pressing, represents a highly effective method for producing virgin oils, as it relies solely on physical forces without heat or solvent, thereby preserving bioactive compounds [22]. This method optimizes the extraction process while simultaneously creating opportunities for the sustainable utilization of residual biomass, addressing both economic and environmental considerations [16]. This produces a press cake, which can be separated using any machine or mechanical system with perforated walls and a bottom on which pressure is applied. This technique allows for the separation of the oil from a solid residue (MOOC), or press cake. The oil extraction was carried out on a mass m_s of 6,5 kg of *Moringa* hulled seeds that had already been heat-treated and pressed using cold extraction. After the first pressing, the resulting oil was collected, while the residual press cake underwent a second pressing to extract the remaining oil and increase the overall extraction yield. The oil obtained from the second pressing was then collected and combined with the oil from the first pressing, resulting in an overall extraction yield of 32.23%. The oil mixture was transferred into a bottle using a funnel equipped with a filter. To remove residual impurities, the oil was left to settle overnight and then subjected to a second filtration (Figure 6).

- $m_o = 2.095$ kg: mass of the extracted oil

The oil extraction yield (R) was estimated using the formula:

$$R_{oil}(\%) = \frac{m_o}{m_s} \cdot 100$$

The filtration stage yields a clear oil with brilliant reflections. It takes place in two stages: a first filtration through cotton cloth which removes solid debris and a second filtration through blotting paper which removes waxes and traces of moisture.

The operating procedure is summarized in the production diagram below, as shown in Figure 7.

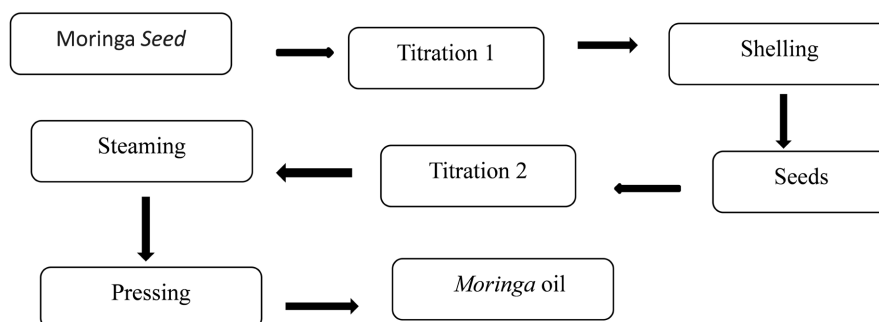


Figure 7. Production chain.

• Preparation of hydroalcoholic extracts

A 1 g portion of *M. oleifera* seed powder and press cake was separately macerated in 10 mL of a methanol-water mixture (80/20, v/v) to determine total phenolic and total flavonoid contents, as well as antioxidant activity. The mixtures

were agitated at 20°C for 24 h and then centrifuged at 3800 rpm for 15 min. The methanolic phases were subsequently collected, vacuum-filtered, and used for the various analyses.

2.2. Determination of Total Phenolic Content (TPC)

The total polyphenol (TPC) content of the different *Moringa oleifera* samples was determined by the Folin-Ciocalteu reagent method, following the protocol described by [23]. 0.5 mL of the extract solution was mixed with 2.5 mL of Folin-Ciocalteu (1/10), then 4 mL of sodium carbonate Na_2CO_3 (7.5%) was added and the mixture was incubated at 45°C for 30 minutes before measuring absorbance at 765 nm. Results were expressed as mg gallic acid equivalent per g of dry matter (mg GAE/g DM) from the calibration curve using gallic acid as the standard.

2.3. Determination of Total Flavonoids Content (TFC)

Total flavonoid content (TFC) was assessed by the aluminum chloride colorimetric method according to [24]. Briefly, 1 mL of the extract solution was placed in a volumetric flask (10 mL) and then 4 mL of distilled water was added to each flask and 0.3 mL of 5% NaNO_2 was also added to the mixture. This was left to stand for 5 minutes before adding 0.3 mL AlCl_3 (10%). Next, 1 mL of 2M NaOH was added to the flask after 6 minutes and made up to 10 mL with distilled water. Absorbance was measured at 415 nm after the mixture had been incubated for 30 minutes. The TFC was expressed as mg quercetin equivalent per g of dry matter (mg QE/g DM) calculated from the equation of the calibration curve using quercetin as a standard.

2.4. Determination of Condensed Tannins (CT)

Condensed tannin concentration was determined using the vanillin colorimetric method [25]. 2 mL of a fresh 1% (w/v) vanillin solution in methanol was mixed with 2 mL of a 25% (v/v) sulfuric acid solution in methanol. Then, 0.5 mL of the previously sample was added to the reaction mixture. The resulting mixture was kept in the dark for 15 min, during which time a red color developed. Absorbance was then measured at 500 nm using a SCILOGEX SP-UV1100 UV-Vis spectrophotometer (Rocky Hill, USA). A reagent blank containing vanillin, sulfuric acid, and methanol was used as a reference. Results were calculated and expressed as mg of catechin equivalents per gram of dry matter (mg CE/g DM).

2.5. Determination of Antioxidant Activity by FRAP

The antioxidant power of the samples, an indicator of their reduction capacity, was assessed using the method described by Gülçin [26]. Briefly, 2.5 mL of 0.2 M sodium phosphate buffer (pH 6.6) and 2.5 mL of 1% (w/v) potassium ferricyanide solution ($\text{K}_3\text{Fe}(\text{CN})_6$) were mixed with 1 mL of the extract solution. After 20 minutes of incubation at 50°C, 2.5 mL of 10% (w/v) trichloroacetic acid was added to the mixture. Ferric chloride (FeCl_3) (0.5 mL at 0.1% w/v) and demineralized

water (2.5 mL) were combined with the supernatant of the solution (2.5 mL).

After 30 minutes of incubation, the solution was measured at λ_{max} 700 nm against a blank. The reducing power of the extract was expressed as milligram equivalents of standard ascorbic acid in grams of dry matter (mg AAE/g DM).

2.6. Determination of Antioxidant Activity by DPPH

The free radical DPPH (2,2-diphenyl-1-picrylhydrazyl) is used to calculate the percent inhibition of extracts. A 0.2 mM ethanolic DPPH solution was prepared, and 0.5 mL was added to 2.5 mL of diluted extract. After 30 min of standing in the dark at room temperature, the absorbance of the combination was measured at 517 nm [27]. The percentage of inhibition, also known as radical scavenging activity (RSA), was calculated for each mixture.

2.7. Fatty Acids Composition Determination

Fatty acid (FA) profiling was performed according to the official analytical method [28]. The FAs were subsequently converted into their corresponding methyl esters before being analyzed using a gas chromatograph (Agilent 6890; Santa Clara, CA 95051, USA) equipped with a CPWAX 52CB column (30 m $\times$ 0.25 mm internal diameter, 0.25 μ m film thickness) and a flame ionization detector (GC-FID). Helium (He) served as the carrier gas (flow rate of 1 mL/min), and 1 μ L of each sample was injected at 220°C (split ratio of 1:50). The oven temperature was set to 180°C for 5 minutes and then raised to 220°C at a rate of 15 °C/min. Detection was performed at 230 °C. Results were presented as the relative percentage of each individual fatty acid peak area.

2.8. Protein Content

Protein content determination was evaluated following DUMAS method, which is based on the combustion of matter to determine the total nitrogen, using a LECO FP628 protein analyzer (LECO Corp., MI, USA) [29]. The total nitrogen content was then converted to PC using a factor of 6.25 and expressed as a percentage of sample dry matter (g/100g DM).

2.9. Minerals Profiling

Mineral analysis was determined according to the method described by Ibourki *et al.* [30]. 1 g of the sample powder was incinerated at 500°C for 2 h. Then, 4 mL of 65% HNO₃ was added, followed by 25 mL of ultrapure water. The solution was injected into a Perkin Elmer Optima 8000 DV spectrometer to quantify the concentrations of minerals zinc (Zn), iron (Fe), boron (B), manganese (Mn), copper (Cu), magnesium (Mg), calcium (Ca), sodium (Na), potassium (K) and phosphorus (P).

2.10. Statistical Analysis

The values presented correspond to the mean $\pm$ standard deviation obtained from two to three repetitions. The study used an ANOVA to assess significant variations

between mean values. A Tukey test was performed, with a significance threshold set at a p-value < 0.05. All statistical analyses were performed using Origin Lab software.

3. Results and Discussion

3.1. Oil Content

This screw press extraction technique, generally used in agricultural campaigns in Senegal, can be considered a cold extraction technique as long as the temperature does not exceed 50°C. The artisanal oil extraction process used in this study for *M. oleifera* yielded 32.23%, calculated based on the quantity of MOSO obtained, as illustrated in **Figure 6**. This is practically the first time such a high yield has been achieved with cold-pressed Moringa oil, whereas various reported values ranged from 24.7% to 27.84% [31] [32]. This yield falls within the broader 30 and 40% range reported for *M. oleifera* seed oil production [33], depending on the variety, geographical origin, agronomic conditions and extraction methods [34]. Furthermore, the 32.23% yield obtained in the present study is competitive with values reported for other mechanical pressing systems. Recent studies have documented yields of 16.12% through cold pressing of Yemeni *M. oleifera* seeds [35], and, 20% - 31% under optimized seed-moisture conditions [36]. The difference observed may also be due to the fact that the oil is always retained in the press cake, unlike with hot extraction. A low moisture content of the seeds (<10%) is recognized as a key factor in improving extraction yield and oil stability during storage, by limiting hydrolysis reactions and microbial growth [36]. Several parameters such as environmental factors, rainfall and harvesting conditions impact the yield, shelf-life and quality of seed oil from oilseed plants [37]. In addition, the optimization of oil extraction from *M. oleifera* seeds is critical for maximizing both yield and the preservation of its valuable bioactive compounds, an endeavor that often involves balancing efficiency with environmental considerations [38]. For instance, mechanical extraction techniques are favored for their ability to yield oil without the use of deleterious solvents, potentially enhancing oil quality and bioactive component preservation [39].

Temperature is a fundamental factor in improving oil extraction efficiency. Experimental data indicates that higher processing temperatures during extraction significantly increase oil yield by reducing viscosity and improving solvent efficiency, although excessive heat may simultaneously degrade thermolabile bioactive compounds [40]. Therefore, the cold-extraction approach utilized in this study serves as a critical strategy to preserve heat-sensitive constituents while achieving a yield that competes effectively with thermal-based extraction methodologies [41].

At the same time, a substantial quantity of by-products, consisting essentially of *M. oleifera* press cake and hulls, was collected. Its utilization in animal feed, dietary supplements, or as a natural fertilizer aligns with sustainable practices by reducing waste and promoting the circular economy [16]. The fertilizing power

of *M. oleifera* press cakes (MOOC) is highlighted by their content of trace elements such as phosphorus and potassium as illustrated in **Table 1**. Further studies would make it possible to evaluate the nutritional potential of these cakes for animals.

Table 1. Analysis of minerals (mg/kg) of *Moringa oleifera* seeds.

Element	Ca	Fe	Mn	Na	P	K	Mg	Zn	Cu	B
Seed	2622.9 ± 27.7	35.5 ± 0.6	20.0 ± 0.1	903.1 ± 4.5	15391.1 ± 67	7239.1 ± 16.0	2447.5 ± 7.4	55.4 ± 0.2	18.4 ± 0.0	6.9 ± 0.0

3.2. Phenolic Compounds Content and Antioxidant Activities

The analysis of phenolic compounds in the seeds is of great importance. The results concerning the polyphenol content and antioxidant activities of the seeds and press cakes are recorded in **Table 2**.

Table 2. Phenolic compounds and antioxidant activity.

Sample	TPC (mg GAE/g DM)	TFC (mg QE/g DM)	CT (mg CE/g DM)	FRAP (mg AAE/g DM)	DPPH (%)
Seeds	1.43 ± 0.06 b	17.64 ± 0.55 a	0.026 ± 0.002 b	8.00 ± 0.44 b	4.73 ± 0.95 a
Cake	2.65 ± 0.04 a	14.86 ± 0.23 b	0.050 ± 0.006 a	17.38 ± 0.88 a	6.08 ± 3.82 a

Results are presented as means ± SD. Different letters (a, b) indicate significant differences between means within the same column ($p < 0.05$).

The total phenolic content (TPC) in seeds of *M. oleifera* is lower than that found in different fractions of *M. oleifera* seeds from Mexico (218.5 mg GAE/100g - 386.9 mg GAE/100g) but that found in cake is within the previous range [42]. The highest content was found in the shell, followed by the kernel, wings, and then the whole seed. These results are consistent with other studies of TPC in *M. oleifera* leaves (161.98 ± 1.44 mg GAE/100g) [43], but smaller than the values of seeds from Malaysia (10.179 ± 2.894 mg GAE/g DM) and Bangladesh [44]. As can be seen, *M. oleifera* cake has higher phenolic and condensed tannin contents, as well as antioxidant activities (FRAP and DPPH). This suggests that the cake (the by-product of oil extraction) retains more phenolic compounds, which may provide stronger antioxidant effects. The seed and cake of *Moringa oleifera* are rich in flavonoids (17.64 ± 0.55 and 14.86 ± 0.23 mg QE/g DM, respectively). These values are close to that found in *M. oleifera* stem bark methanolic extract from Nigeria but are much smaller than the values found in the other extracts from the different parts of *M. oleifera* (bark, flower, food powder, stalk, leaf, and root) [45]. Another study recorded a lower flavonoid content in seeds than that in our samples [46]. The lower number of flavonoids in cake than in seeds may be explained by the fact that they are either heat-sensitive or soluble in the extracted oil. The cake of *M. oleifera* shows over twice the antioxidant power (FRAP) compared to the seeds as showed in **Table 2**. However, the DPPH antioxidant assay exhibited

low percentages for both seeds and cake. Similar results were obtained for seeds from Bangladesh; the methanol and acetone extracts showed low percentages of inhibition of DPPH even at high concentration (500 µg/mL), compared to the water extract, which showed an IC₅₀ of 36.89 ± 0.15 [45].

3.3. Fatty Acids Composition of MOSO

Table 3 presents the fatty acid (FA) composition of MOSO determined in this study. The oil was found to contain a high level of monounsaturated fatty acids up to 73.27%. Oleic (C18:1 *n*-7) was the predominant fatty acid, which accounted for 69.56% of the total fatty acids. The content of 18-C polyunsaturated fatty acids remains quite low and consists of linoleic fatty acid (C18:2 *n*-6) (0.64%), linolenic acid (C18:3 *n*-3) (0.14%). The content of total saturates, that is, tetradecanoic (C14:0), palmitic (C16:0), stearic (C18:0), arachidic (C20:0), in the oil was 17.36%, of which C18:0 was the dominant acid.

Table 3. Fatty acid composition (gram per 100 g of MOSO).

Analytes	C14:0	C16:0	C16:1	C18:0	C18:1	C18:2	C18:3	C20:0	C20:1	C22:0	Other peaks
<i>Moringa</i>	0.08 ± 0.01	5.54 ± 0.1	1.38 ± 0.1	7.19 ± 0.1	69.56 ± 0.1	0.64 ± 0.01	0.14 ± 0.01	4.55 ± 0.1	2.33 ± 0.1	6.82 ± 0.1	1.64 ± 0.1

The concentration of major fatty acids, C18:1, C18:0, and C16:0 of the oil, investigated in the present study were in close agreement with those reported by Tsaknis *et al.* for *M. oleifera* seed oil from the Mbololo variety in Kenya [46]. The amounts of C20:0 (4.55%), and C20:1 (2.33%) in the oil varied to a small extent from those reported in the literature [46]. The amount of gadoleic acid (C20:1) (2.33%) was well in line, and C16:1 (1.38%) was also detected in the present analysis, which was not reported in the kenyan Mbololo study. Furthermore, recent studies have revealed palmitoleic acid levels ranging from 1.10% to 1.46%, values consistently close to those observed in the present study [47]. Such findings corroborate the hypothesis that regional environmental stressors in Senegal may stimulate the biosynthesis of secondary metabolites as an adaptive mechanism to drought conditions [48]. The fatty acid profile in this study is characterized by the predominance of oleic acid and a very high ratio of monounsaturated to saturated fatty acids. Consequently, the high oleic acid content, often exceeding 70% in various cultivars, positions *M. oleifera* as a competitive alternative to premium vegetable oils like olive oil [49].

Given the simultaneous presence of water (three rivers) and arable land in Senegal, *M. oleifera* appears to be a plant potentially capable of replacing expensive imported vegetable oils with high oleic acid content, such as olive or sunflower oil in the dietary fats.

3.4. Protein and Minerals Content

Analysis revealed that Moringa seeds contain 7.74 g/100g of protein, 2.92 g/100g

of ash, 44.57 g/100g of carbohydrates, and 553.68 kcal/100g of energy, giving the seeds good nutritional value [17]. The various mineral elements are listed in the table above.

Ten minerals were analyzed in this study, including five macro-elements (K, Ca, P, Mg, and Na) and five micro-elements (Fe, Cu, Mn, B, and Zn), in the seeds of *M. oleifera*, as compiled in Table 1. Mineral profile of MOSO is dominated by phosphorus (15,391.1 mg/kg), potassium (7,239.1 mg/kg), calcium (2,622.9 mg/kg), and magnesium (2,447.5 mg/kg), respectively. These mineral compositions contribute to the seed's overall biological stability, facilitating better extraction efficiency and potentially enhancing the functionality of the resulting oil in diverse industrial applications [39]. The mineral content of the investigated *M. Oleifera* oil are substantially higher than those reported for *M. oleifera* seeds in a recent review, approximately 1,100, 2,358, 300, and 240 mg/kg, respectively for phosphorus, potassium, calcium and magnesium, although these differences may reflect geographical origin, sample matrix, and analytical methodology [7]. Beyond their value as compositional markers, these minerals may enhance the biological and nutritional relevance of MOSO, with phosphorus contributing to cellular membrane structure, potassium supporting electrolyte and blood-pressure regulation, and calcium and magnesium participating in bone maintenance, muscle function, nerve transmission, and enzymatic metabolism [50].

Iron (35.5 mg/kg) and zinc (55.4 mg/kg) are present in low concentrations, in comparison to primary minerals like potassium, yet these micronutrients remain critical for essential physiological functions such as oxygen transport and immune response regulation [51]. Such trace element concentrations, while modest, align with previous observations where metabolic roles, specifically iron's involvement in hemoglobin synthesis and zinc's contribution to reproductive health, underscore the oil's potential as a functional dietary supplement [52].

Comparative mineral profiling suggests that while calcium remains a predominant element in *Moringa* tissues [9] [53], the specific concentrations within Senegalese MOSO may differ significantly from those reported in studies of other geographical regions, highlighting the role of local edaphic factors in mineral sequestration [54].

4. Conclusion

In this study, cold-pressing of *M. oleifera* seeds harvested in Senegal, antioxidant potential and nutritional profile, of the resulting seed oil (MOSO) were performed. Mechanical cold extraction has yielded very promising results that could be replicated on farms across the country. Furthermore, MOSO, and particularly the press cake (MOCO), have demonstrated significant antioxidant capacity, thereby confirming their nutritional, pharmacological, and cosmetic value. In addition, the determination of fatty acid composition of MOSO from Senegal showed that oleic acid, stearic acid and palmitic acid, respectively, were the dominant fatty acid, with a high ratio of monounsaturated to saturated fatty acid. MOSO also revealed a

high content of macro-minerals, notably phosphorus, potassium, calcium and magnesium, as well as trace elements, such as zinc and iron. Overall, these results highlight the very real potential of Senegalese *M. oleifera* seed oil (MOSO) for food and industrial applications, as well as for the development of high-nutritional-value formulations based on stable blends with other oils rich in linoleic acid. Further investigations are needed to evaluate its storage stability, safety, and bioavailability.

Author Contributions

D.A. and B.E. wrote the manuscript; F.M., D.M., and F.I. made the tables; N.A. and G.S. wrote the conclusion.

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Data Availability Statement

The datasets generated during and/or analysed during the current study are available from the corresponding author on reasonable request.

Ethics, Consent to Participate, and Consent to Publish Declarations

not applicable.

Conflicts of Interest

The authors declare no competing interest.

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