

Phytochemical Screening and Antioxidant Potential of Hydromethanolic Extracts of *Moringa oleifera* Lam. Flowers from Senegal

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Abstract

This study investigates the phytochemical composition and antioxidant potential of hydromethanolic extract of *Moringa oleifera* L. flowers harvested in Kaolack, Senegal. Phytochemical screening revealed the presence of several classes of bioactive compounds (polyphenols, flavonoids, alkaloids, sterols, polyterpenes, leucoanthocyanins, etc.), whose distribution varies according to the polarity of the extraction solvents. Quantitative analysis showed a significant concentration of phenolic acids (31.47 ± 0.10 mg GAE/g) and a high content of flavonoids (291 ± 20.035 mg QE/g), confirming a high richness in antioxidants. Biological activity, assessed by DPPH and FRAP tests, indicated a percentage of inhibition of $48.62 \pm 2.34\%$ (DPPH) and a reduction capacity of 18.609 ± 0.552 mg EAA/g (FRAP). In addition, pigment analysis revealed the presence of chlorophyll a (1.37 mg/100g), chlorophyll b (3.70 mg/100g) and carotenoids (7.7 mg/kg), contributing to overall antioxidant activity. On the basis of the results obtained, moringa flowers are found to be a potential source of natural antioxidants due to their marked antioxidant activity.

Keywords

Moringa oleifera Flowers, Senegal, Secondary Metabolites, Antioxidant Activity

1. Introduction

Moringa oleifera is a globally recognized tree species, primarily valued for its nutritional and medicinal attributes [1]. While various parts of the plant, including

leaves, seeds, and pods, have been extensively studied for their therapeutic potential, research on the phytochemical composition and antioxidant properties of *Moringa oleifera* flowers remains comparatively limited [1]. However, these floral components are increasingly recognized as a rich source of bioactive secondary metabolites, including carotenoids, flavonoids, and phenolics, which contribute to their noted antioxidant and anti-inflammatory activities [2] [3]. Specifically, empirical evidence suggests that *M. oleifera* flowers exhibit elevated levels of total flavonoids and anthocyanins, which correlate with high DPPH radical scavenging activity [4]. This suggests their promising role in neutralizing free radicals and mitigating oxidative stress, a primary contributor to various chronic diseases [5].

In West Africa, particularly in Senegal, *Moringa oleifera* flowers are traditionally used for their beneficial properties for eye health. This potential of Moringa is attributed to a high flavonoids and carotenoids content that supports vision and combats oxidative damage [5]-[7]. These compounds, including notable antioxidants like quercetin, gallic acid, and ferulic acid, are instrumental in mitigating oxidative stress, thereby preventing cellular damage [8]. This endeavor is particularly pertinent given the widespread cultivation of *Moringa Oleifera* in Senegal and the general paucity of data on the specific phytochemical profiles of locally sourced plant materials, which can vary significantly due to environmental factors and genetic diversity [9].

To date, scientific data relating to the biochemical profile of flowers harvested in Senegal remain incomplete, thus limiting their formal integration into the local phytotherapy or agro-industry sectors. The current study aims to systematically investigate the phytochemical constituents present in *Moringa oleifera* flowers harvested in Senegal, quantifying their phenolic and flavonoid content, and assessing their antioxidant potential. This research was motivated by the need to understand the potential of *Moringa oleifera* flowers to naturally manage oxidative stress and other similar diseases.

2. Materials and Methods

2.1. Plant Material

The plant material used in this study consists of *Moringa oleifera* L. flowers (**Figure 1**). These were collected in the Kaolack region (Senegal), located at the approximate geographical coordinates 14°08'34" North and 16°04'21" West in August 2025, during the rainy season. The samples were identified and authenticated at the Botanic Laboratory of the Fundamental Institute of Black Africa at Cheikh Anta Diop University of Dakar.

After harvesting, the samples were carefully cleaned with distilled water, then dried at room temperature and away from direct light to preserve the integrity of the heat-labile bioactive compounds. Once completely dried, the flowers were pulverized using an electric grinder to produce a fine, homogeneous powder (**Figure 1** and **Figure 2**). This powder was stored in airtight jars, in a cool dry place, to prevent any degradation or contamination before analysis.



Figure 1. *Moringa oleifera* flowers.



Figure 2. Dried *Moringa oleifera* flower powder.

2.2. Extraction Process

Secondary metabolites were extracted by cold maceration along a gradient of increasing polarity. A 5 g sample of *Moringa oleifera* flower powder was initially immersed in 50 mL of hexane in an Erlenmeyer flask. To prevent solvent evaporation and protect the photosensitive compounds, the container was sealed with aluminum foil. After 24 hours of maceration in the dark and at room temperature, the mixture was filtered. The resulting solid residue was then subjected to successive extractions using solvents of higher polarity: Ethyl acetate, ethanol, and finally distilled water. This method of successive exhaustion allows the fractionation of bioactive compounds according to their chemical affinity, ranging from lipophilic molecules to the most hydrophilic molecules. The different extracts obtained with all solvents are gathered in **Figure 3**.

The extraction scheme of the secondary metabolites obtained from *Moringa oleifera* flowers is represented below in **Figure 4**.



Figure 3. Extracts from the various solvents.

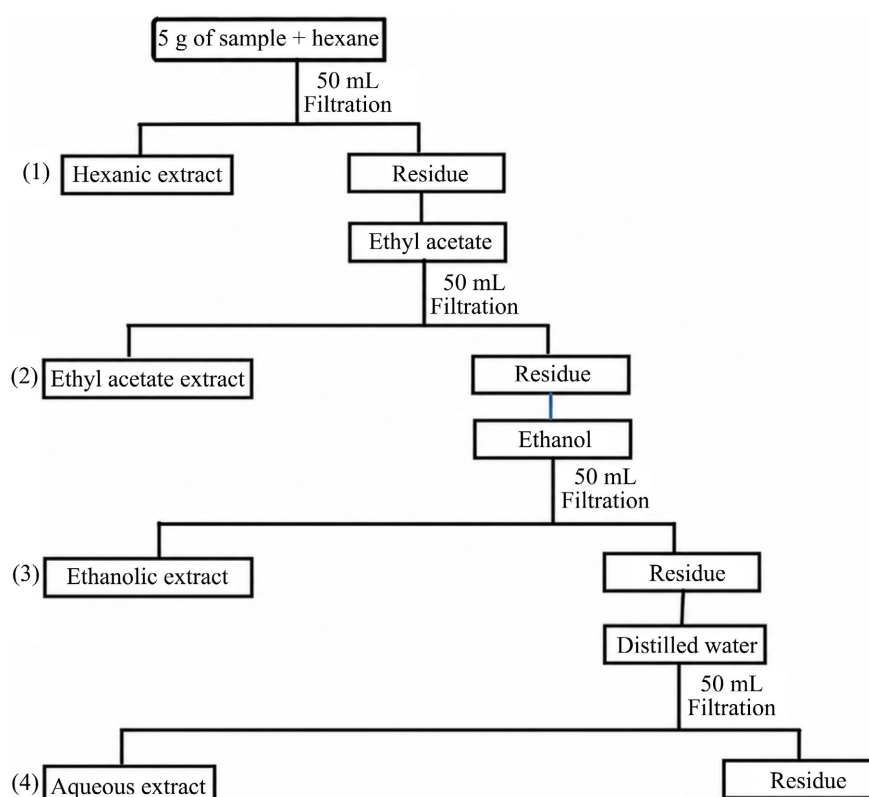


Figure 4. Secondary metabolite extraction scheme.

2.3. Phytochemical Characterization Techniques

Phytochemical screening consists of a preliminary qualitative analysis based on specific color and precipitation reactions. These tests confirm the presence or absence of the main families of secondary metabolites in *Moringa oleifera* flower extracts.

As part of this work, the investigation focused on identifying the following chemical groups.

- Phenolic compounds: total polyphenols, flavonoids, tannins (catechins and gallinules), anthocyanins, and coumarins.

- Terpenic and steroidal compounds: sterols, polyterpenes, and saponins.
- Other metabolites: alkaloids, mucilage, and catechols.

The identification of these different groups was carried out by following the experimental protocols and characterization techniques described by [10] [11].

2.3.1. Polyphénol Detection Test

To detect polyphenols, we poured 2 mL of each extract into each of the two tubes (the control and the test) and then added a few drops of 2% ferric chloride (FeCl_3) alcoholic solution. The appearance of a bluish-black or greenish-black color indicates a positive test, confirming the presence of polyphenols (Figure 5).

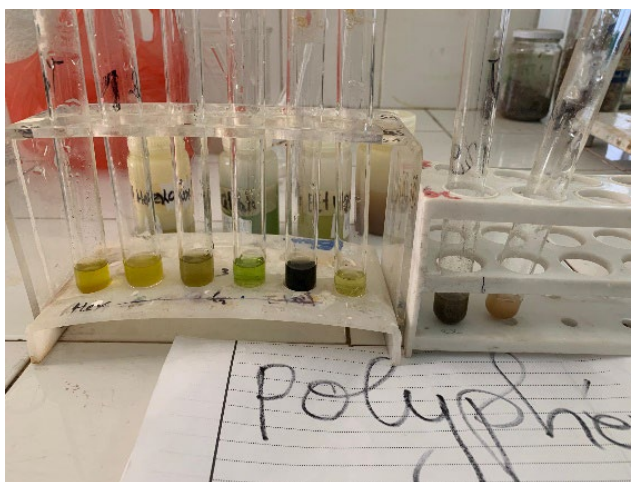


Figure 5. Presence of polyphenols.

2.3.2. Flavonoïds Detection Test

This test involves adding 1 mL of aqueous extract to 1 mL of concentrated hydrochloric acid (HCl) in the presence of a few magnesium shavings. The appearance of a color ranging from orange to purple indicates the presence of flavonoids (Figure 6).



Figure 6. Presence of flavonoids.

2.3.3. Alkaloid Detection Test

This test is based on the ability of alkaloids to combine with heavy metals. 1 mL of each extract (hexane, ethyl acetate, methanolic and aqueous) is reconstituted in a few mL of HCl diluted by half (**Figure 7**).



Figure 7. Presence of alkaloids.

The formation of a yellow precipitate, after adding a few drops of Mayer's reagent (1.35 g of HgCl_2 + 5 g of KI in 100 mL of dilute H_2O), indicates the presence of alkaloids.

2.3.4. Sterols and Polyterpenes Detection Test

Sterols and polyterpenes were investigated using the Liebermann reaction. One milliliter of each extract was dissolved in one milliliter of acetic anhydride. 0.5 mL of concentrated sulfuric acid (H_2SO_4) was then added to the solution. The appearance of a purple ring at the interface, which then turns blue and finally green, indicates a positive reaction (**Figure 8**).



Figure 8. Presence of sterols and polyterpenes.

2.3.5. Leucoanthocyanins and Catechols Detection

Leucoanthocyanins are characterized by the cyanidin reaction. One mL of extract is added to one mL of concentrated hydrochloric acid (without magnesium spongy) and the mixture is heated for 15 minutes in a water bath. In the presence of leucoanthocyanins, a cherry-red or purplish color appears. Catechols produce a reddish-brown tint (**Figure 9**).

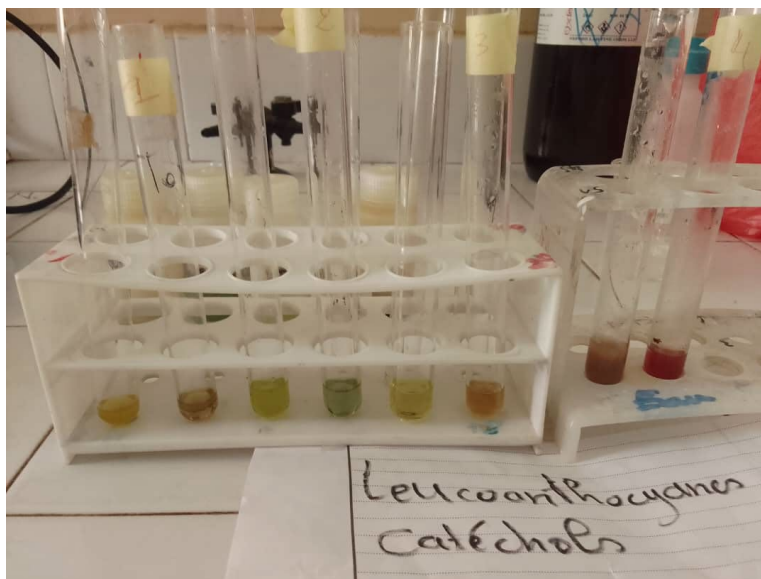


Figure 9. Presence of Leucoanthocyanins and catechols.

2.3.6. Coumarin Detection Test

To 5 mL of each extract, 2 mL of warm distilled water is added. The solution is divided into two test tubes. The presence of coumarins is investigated after adding 0.5 mL of a 25% ammonium hydroxide (NH_4OH) solution to one of the tubes and observing fluorescence under a 365 nm UV lamp. Intense blue fluorescence in the tube containing the ammonia indicates the presence of coumarins (**Figure 10**).

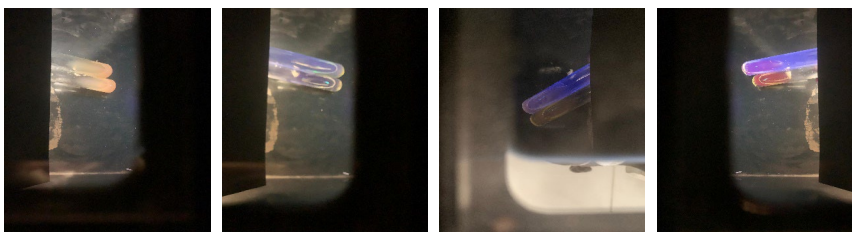
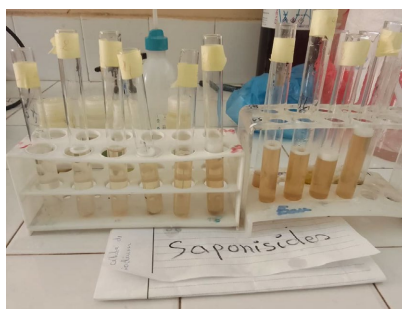


Figure 10. Presence of coumarins.

2.3.7. Saponoside Detection Test

1 gram of plant material is added to 100 mL of distilled water and gently boiled for 30 minutes. After cooling, filter the mixture, add 1 mL of the extract to each tube, and dilute to 10 mL with distilled water if necessary. Shake each tube manually for 30 seconds. After 15 minutes of stand, persistent foam exceeding 1 cm in height indicates the presence of saponins (**Figure 11**).



Juste après agitation

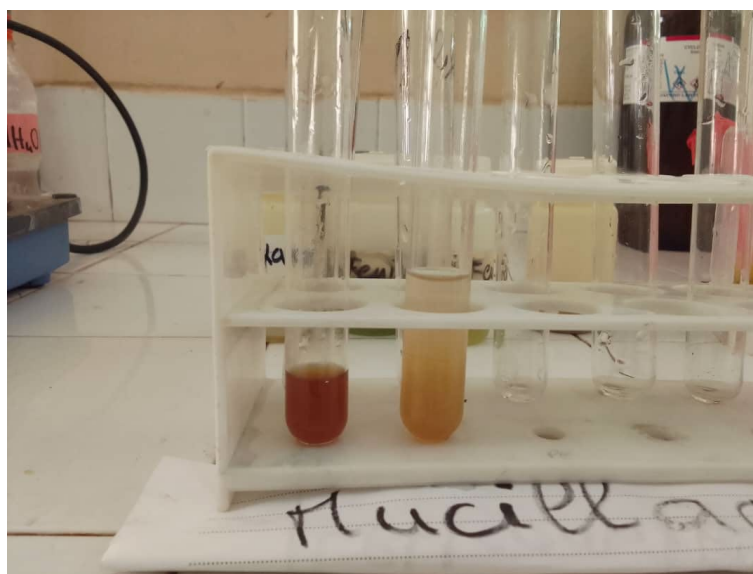


15 min après agitation

Figure 11. Presence of saponosides.

2.3.8. Mucilage Detection Test

Mucilages are plant substances, composed of polysaccharides, that swell upon contact with water and take on a viscous, sometimes sticky, consistency similar to that of gelatin. To 1 mL of a 10% decoction, 5 mL of absolute ethanol are added. The formation of a flocculent precipitate after mixing indicates the presence of mucilages (**Figure 12**).

**Figure 12.** Presence of mucilage.

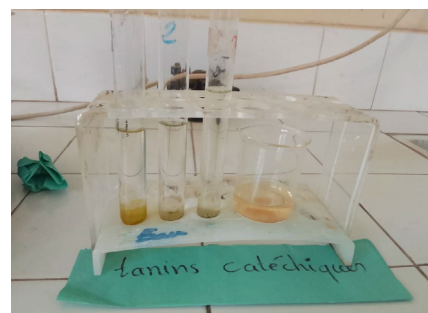
2.3.9. Test for the Detection of Catechins and Gallic Tannins

The search for catechin-type tannins was performed using Stiasny's reagent. Five (5) mL of each extract were evaporated to dryness. After adding 15 mL of Stiasny's reagent to the residue, the mixture was incubated in a water bath at 80°C for 30 min. Observation of a precipitate in the form of large flakes confirmed the presence of catechin-type tannins (**Figure 13**).

For the determination of gallic tannins, the previous solution was filtered. The filtrate was collected and saturated with sodium acetate. If the addition of 3 drops of FeCl_3 causes an intense blue-black color, this indicates the presence of gallic tannins (**Figure 14**).



Dry extract + stiasny



After 30 min in a bain marie

Figure 13. Presence of catechins.**Figure 14.** Presence of gallic tannins.

2.4. Secondary Metabolite Titration

A 1 g portion of moringa flower powder was macerated in 10 ml of an 80/20 (v/v) methanol-water mixture to determine the total phenol and flavonoid content, as well as the antioxidant activity. The mixture was stirred at 20°C for 24 hours, then centrifuged at 3800 rpm for 15 minutes. The methanolic phase was extracted, filtered under vacuum, and transferred for analysis by various tests.

2.4.1. Polyphénols Totaux [11]

Add 0.25 mL of the previously prepared extract to 1.25 mL of Folin-Ciocalteu reagent (1/10) in distilled water containing 2 mL of sodium carbonate (7.5%). Stir the mixture, then incubate in a water bath (45°C) for 30 minutes; then measure the absorbance at 765 nm. The blank contains all the reagents except the extract.

A calibration curve was performed using gallic acid as a standard and the results were expressed in mg of gallic acid equivalents per gram of dry matter (mg GAE/g DM).

2.4.2. Determination of Flavonoid Content [12]

In a 10 mL volumetric flask, 1 mL of diluted extract was introduced, followed by 4 mL of distilled water and 0.3 mL of 5% sodium nitrite (NaNO_2). After 5 minutes, 0.3 mL of 10% aluminum chloride (AlCl_3) solution was added and the mixture

was allowed to stand for 6 minutes. Then, 1 mL of 2 M NaOH was added, and the volume was adjusted to 10 mL with distilled water. After incubation at room temperature for 30 min, absorbance was measured using a UV-Visible spectrophotometer at 415 nm.

A calibration curve was generated using quercetin, and the results were expressed as mg of quercetin equivalents per gram of dry matter (mg QE/g DM).

2.4.3. Antioxidant Activity by DPPH [13]

5 mL of a 0.2 mM DPPH• methanolic solution was added to 2.5 mL of phenolic extract. The mixture was incubated in the dark at room temperature for 30 minutes, and then the absorbance at 517 nm was measured.

The percentage of inhibition or free radical scavenging activity corresponds to the decolorization of the mixture. A control is prepared with 0.8 ml of DPPH and 4 ml of methanol; the blank consists of methanol alone.

Antioxidant activity, expressed as a percentage of inhibition (%), is done by the relation:

$$\% \text{ d'inhibition} = \frac{Ac - Ae}{Ac} \times 100$$

2.4.4. Antioxidant Activity by FRAP [14]

An aliquot of 0.5 mL of the diluted extract was mixed with 1.25 mL of potassium phosphate buffer solution (0.2 M, pH 6.6) and 1.25 mL of 1% potassium ferricyanide ($K_3[Fe(CN)_6]$). The resulting mixture was incubated at 50°C for 20 min. Then, 1.25 mL of 10% trichloroacetic acid (CCl_3COOH) was added, and the mixture was centrifuged at 3000 rpm for 10 min. Finally, 1.25 mL of the supernatant was mixed with 1.25 mL of distilled water and 0.25 mL of 0.1% ferric chloride ($FeCl_3$). The absorbance of each sample was measured at 700 nm. A calibration curve was established using ascorbic acid as the standard, and the results were expressed as mg of ascorbic acid equivalents per gram of dry matter (mg AA/g DM).

2.4.5. Chlorophyll Pigments and Carotenoids Titration

The entire procedure was performed in the dark to prevent photodegradation of the pigments. Following a slightly modified protocol, 0.5 g of flower powder was mixed with 10 mL of 80% (v/v) acetone. The extract was shaken and then incubated for one hour in the dark before being centrifuged in airtight tubes at 3500 rpm for 15 minutes.

The supernatant was recovered for absorbance measurement at wavelengths of 663 nm and 645 nm for chlorophylls a and b, respectively, and at 470 nm for total carotenoids. The concentrations of chlorophyll a, chlorophyll b, and the sum of carotenoids (xanthophylls and carotenes) were expressed in g/100g dry matter, according to the following equations [15] [16].

$$\text{Carotenoides totaux (mg/kg)} = \frac{A_{470} \times 10^6}{2000 \times 100 \times L}$$

$$\text{Chlorophylles totaux (mg/kg)} = \frac{A_{670} \times 10^6}{613 \times 100 \times L}$$

2.5. Statistical Analysis

The results, presented as mean values $\pm \sigma$ (standard deviation, $n = 3$), were obtained using ANOVA software.

3. Result and Discussion

The results of the identification of secondary metabolites from the screening of *Moringa oleifera* flowers are presented in this section.

3.1. Phytochemical Screening

The phytochemical analysis of *Moringa oleifera* flower extracts was carried out according to standard colorimetric and precipitation protocols. The qualitative results, highlighting the presence of different classes of secondary metabolites, are summarized in **Table 1**.

Table 1. Result of phytochemical screening.

Family of compounds	Extracts			
	Hexanic	Ethyl acetate (AcOEt)	Ethanol (EtOH)	Aqueous
Polyphenols	-	+	+	+
Flavonoids	-	+	+	+
Alkaloids	+	+	+	+
Sterols and Polyterpenes	+	+	+	+
Catechols	-	-	-	+
Leucoanthocyanins	+	+	+	+
Coumarins	+	+	-	-
Saponosides			-	
Mucilages			+	
Catechetical tannins	-	-	-	+
Gallic tannins	-	-	-	-

+ = present, - = absent.

Phytochemical screening of *Moringa oleifera* flower extracts reveals a variable distribution of secondary metabolites depending on the polarity of the solvents used (hexane, ethyl acetate, ethanolic and aqueous). This variability underscores the importance of employing diverse extraction methods to comprehensively characterize the phytochemical landscape of *Moringa oleifera* flowers and fully harness their medicinal potential.

Polyphenols and flavonoids are absent in the hexane extract but present in the ethyl acetate, ethanolic, and aqueous extracts. This distribution is consistent with the polar nature of these compounds, which are generally best extracted by solvents of intermediate to high polarity [17] [18]. These results suggest that *Moringa oleifera* flowers are an important source of phenolic compounds, known for their strong antioxidant activity and ability to neutralize free radicals, as shown in previous studies [19] [20].

Alkaloids, sterols and polyterpenes, as well as leucoanthocyanins, are detected in all extracts, indicating their wide distribution and ability to be solubilized in solvents of varying polarities.

These secondary metabolites possess a wide range of biological activities, including antioxidant, anti-inflammatory, antidiabetic, antitumor and antimicrobial properties, thus giving this plant significant therapeutic potential [21]-[23].

Catechols were detected only in the aqueous extract, which is explained by their high polarity and preferential solubility in polar solvents. Similarly, catechin tannins were found primarily in the aqueous extract, confirming their hydrophilic nature and affinity for highly polar solvents. These observations are consistent with the general principles of phenolic compound extraction, where solvent polarity influences solubility and metabolite recovery [24]. Optimizing solvent systems during extraction is crucial for maximizing the yield and diversity of bioactive phytochemicals, thereby enhancing the comprehensive assessment of their therapeutic efficacy. Furthermore, the selection of appropriate extraction techniques directly impacts the isolation efficiency of specific secondary metabolites, influencing both the quantitative yield and qualitative profile of the resultant extracts [25].

Coumarins are present in the hexane and ethyl acetate extracts, but absent in the ethanolic and aqueous extracts, suggesting an affinity for solvents of low to medium polarity. This behavior is consistent with studies showing that the solubility and extraction of bioactive compounds, such as coumarins, depend on the polarity of the solvent used. Coumarins, for instance, are more efficiently isolated using solvents of moderate polarity [26].

Saponins were not detected in the extracts studied, which may be due either to their absence in the analyzed flowers or to a concentration too low to be detected by qualitative tests. In contrast, mucilage was present only in the aqueous extract, which is expected given its highly hydrophilic nature.

Finally, gallic tannins are absent from all extracts, which indicates either their absence in the studied matrix, or their presence at concentrations below the detection threshold.

In summary, the diversity of identified metabolites highlights the presence of flavonoid polyphenols, alkaloids and other secondary metabolites, thus underscoring the pharmacological potential of *Moringa oleifera* flowers and justifying the performance of additional quantitative analyses, such as total dosages and antioxidant activity tests (DPPH and FRAP).

3.2. Biological Activities

3.2.1. Phenolic Compounds

Phenolic compounds are present in most plant tissues, including edible parts such as fruits, seeds, leaves, flowers, stems, and roots [27]. Phenolic compounds constitute the most widespread group of secondary metabolites in plants and are often preferentially extracted by hydroethanolic or methanolic solutions due to their polarity [17]. The structural diversity of these phenolic compounds, particularly the number and position of hydroxyl groups, plays a critical role in their radical scavenging capacity [28] [29]. Previous studies have demonstrated that solvent polarity significantly influences both the yield of total phenolic and flavonoid content and the corresponding antioxidant capacity [30] [31]. These compounds exhibit various activities, including anti-inflammatory, anti-aging, antiproliferative, and antioxidant properties [32].

Therefore, given the countless biological properties of this class of compounds, the polyphenol and flavonoid contents of methanol-water extracts of *Moringa* flowers and their antioxidant potential were determined.

1) Polyphénols Content

The study revealed a high polyphenol content in *Moringa oleifera* flowers, estimated at 31.47 ± 0.10 mg GAE/g dry matter. This value is higher than that reported by [2], who observed a polyphenol content of 19.31 ± 1.79 mg GAE/g, indicating a greater richness in phenolic compounds in the flower extract of Senegalese *Moringa*. A comparable value was reported for the leaves of this plant by [33], with a polyphenol content of 32.90 ± 4.38 mg GAE/g, suggesting that the flowers in the study have a polyphenol concentration close to that of the leaves, which are traditionally considered to be particularly rich in phenolic compounds.

The discrepancies observed between the different studies can be attributed to the experimental conditions, including the extraction solvent, the method used, and the origin of the plant material.

2) Flavonoids Content

Flavonoids are a group of polyphenolic compounds with beneficial effects on human and animal health. They are an indispensable component in a variety of beneficial applications, including nutraceutical, pharmaceutical and cosmetic, due to their antioxidant, anti-inflammatory, antimutagenic, antibacterial and anti-cancer function [34]. *Moringa Oleifera* flowers have exhibited an exceptionally high flavonoid content, with a value of 291 ± 20.035 mg EQ/g DM. This richness in phenolic compounds, involved in particular in the pigmentation and organoleptic properties of flowers, confirms their important role as a source of secondary metabolites within the plant

In comparison, much lower flavonoid concentration levels (2.80 mg/100g) in *Moringa* flowers, have already been reported [35]. In addition, several analytical studies have revealed that high levels of total phenolic compounds and flavonoids, such as quercetin and kaempferol, are the main determinants of the overall antioxidant capacity [36]-[38].

The significant geographical variation of flavonoid content in moringa flowers is due to disparate agroclimatic conditions, which dictate the biosynthetic pathways and secondary metabolite accumulation in different cultivation regions [39].

3.2.2. Pigments

The study revealed the pigment, chlorophyll, and carotenoid content of *Moringa oleifera* flowers. The chlorophyll was present at a concentration of 1.37 mg/100g dry matter, while chlorophyll b was more abundant, reaching 3.70 mg/100g dry matter. Carotenoids were present at a concentration of 7.7 mg/100g dry matter. Notably, the synthesis of these compounds, particularly, is often modulated by specific lighting conditions, which function as environmental interfaces for plant adaptive responses [40]. Fundamental pigments are chlorophylls, responsible for the green color of plants, whereas carotenoids and anthocyanins contribute the vibrant yellow, orange, and purple hues observed in various *Moringa* floral accessions. These pigments, specifically carotenoids, coexist alongside flavonoids like rhamnetin and isoquercitrin within the floral tissues, further bolstering the extract's comprehensive antioxidant profile [41].

The role of plant pigments is to protect the delicate reproductive tissues of the flowers against photo-oxidative damage induced by intense solar radiation, while simultaneously acting as bioactive co-factors that synergistically enhance the overall radical-scavenging potential of the plant extracts [42]. Additionally, ethanolic extracts from these floral tissues demonstrate broad-spectrum UV absorption peaks between 240 - 280 nm and 300 - 550 nm, suggesting that these secondary metabolites serve as natural photoprotective agents against solar radiation [43]. These bioactive compounds are now attracting increasing interest as natural colorants and health-promoting agents in the food and pharmaceutical industries [44]. Beyond these pigments, the presence of various alkaloids and sulfur-containing compounds further diversifies the phytochemical landscape of the flowers, potentially contributing to their pharmacological efficacy [45].

3.2.3. Antioxidant Activity

An antioxidant is a compound capable of inhibiting oxidation induced by another molecule, thereby safeguarding cellular integrity by neutralizing reactive oxygen species that might otherwise disrupt physiological homeostasis. In this context, the high concentrations of secondary metabolites found in *Moringa oleifera* flowers serve as a robust defense system, mirroring the plant's resilience against environmental stressors in the Sahelian region [46] [47]. The antioxidant activity of *Moringa* flowers was controlled by two different methods (FRAP and DPPH).

1) FRAP

The FRAP test is used to measure the combined (total) antioxidant activity of reducing antioxidants (electron donors) in a given sample. The antioxidants that react in the FRAP assay are those that can reduce ferric ions (Fe^{3+}) to ferrous ions (Fe^{2+}) under the reaction conditions used. This reduction acts as a signal or indicator of reaction, and is linked to a color change [48] [49]. The FRAP test per-

formed on extracts of *Moringa oleifera* flower revealed a value of 18.609 ± 0.552 mg EAA/g, indicating a very high antioxidant reducing activity. These results are close to those of other studies which have reported a FRAP reduction activity of 16.42 mg EAA/g for flower extracts obtained under optimal desirability conditions (90%) [35]. This ability to reduce ferric ions is primarily attributed to the abundance of bioactive compounds present in the flowers, including flavonoids and phenolic acids, which act as electron donors. This assay serves as a complementary metric to the DPPH radical scavenging method, providing a comprehensive assessment of the electron-donating capacity of the floral phytochemical pool [50].

2) DPPH

DPPH is a complementary method utilized to evaluate radical scavenging potential, operating through the donation of hydrogen atoms or electrons to the stable 2,2-diphenyl-1-picrylhydrazyl radical, which undergoes a colorimetric shift from purple to yellow upon reduction [51].

The results of the study gave a percentage of DPPH radical inhibition of $48.62\% \pm 2.34\%$ for a methanol-water extract (80/20, v/v) of *Moringa oleifera* flowers, indicating average antioxidant activity. Studies have reported DPPH radical inhibition percentages exceeding 80% at concentrations of 100 µg/mL, indicating a potent antioxidant effect consistent with the high phenolic content inherent to these floral tissues [52].

However, compared to the results of study [2] where an inhibition of $33.89\% \pm 1.36\%$ was observed at only 200 µg/mL our extract requires a greater amount of active material to induce a similar effect, indicating a lower relative efficacy of our sample. The difference observed between the two studies can be explained by the nature of the extraction solvent, the concentration of the extracts, and the geographical location. The antioxidant activity of *Moringa oleifera* flowers, as well as the potential for incorporation into nutraceutical formulations, demonstrate that these extracts are promising for mitigating pathologies related to oxidative stress by modulating redox-sensitive signaling pathways [52].

4. Conclusion

The findings of this study indicate that *Moringa Oleifera* flowers from Senegal are a good source of variable bioactive substances such as total phenolic compounds, sterols, polyterpenes, coumarins, pigments and possesses intense antioxidant properties. Phytochemical screening revealed a wide diversity of secondary metabolites, the distribution of which is closely linked to the polarity of the extraction solvents. Quantification revealed exceptional levels of flavonoids and a significant concentration of phenolic acids, chlorophyll and carotenoids. The study also revealed an interesting potential for reduction, in terms of free radical scavenging, of *Moringa oleifera* leaf extracts, induced by the high presence of phenolic compounds and pigments. Given the in vitro antioxidant potential of *Moringa Oleifera* L. flowers, this study could support the hypothesis that they can be used in the

treatment of several pathologies, including eye disorders, probably due to damage caused by sun exposure. These results contribute to the establishment of data on the medicinal potential and pharmacological properties of *Moringa oleifera* flowers. Further studies, including chromatographic studies, would be needed to precisely identify the types of flavonoids and phenolic acids responsible for the activity and to better optimize their beneficial effects.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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