

Research Article

Evaluation of extraction methods on the physicochemical quality of noni oil (*Morinda citrifolia*) grown in Senegal

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Abstract

This study aimed to evaluate the effects of two extraction methods on the physicochemical quality of oil extracted from *Morinda citrifolia* seeds. The oil was extracted by maceration and Soxhlet methods using heptane as solvent. The analyses included moisture, refractive index, acid value, acidity, peroxide value, iodine value and saponification value. The seed recovery yield was 6.635 ± 0.841 %. The oil extraction yields by maceration (cold extraction) and Soxhlet extraction were 8.179% and 8.238%, respectively. Evaluation of the physicochemical parameters revealed the following results: 0.318% moisture in the oil extracted by maceration compared to 0.075 % in that obtained by Soxhlet; a refractive index of 1.464 for both oils, 4.941 mg KOH/g for the maceration and 7.940 mg KOH/g for the Soxhlet oil; an acidity of 2.483% in the maceration oil and 3.991% in the Soxhlet oil; a peroxide index of 8.353 meqO₂/kg for the maceration oil and 7.250 meqO₂/kg for the Soxhlet oil; an iodine index of 74.871 g/100g for the maceration oil and 72.333 g/100g for the Soxhlet oil; finally, a saponification index of 145.509 mg KOH/g for the maceration oil and 191.124 mg KOH/g for the oil extracted by Soxhlet. These results indicate that extraction methods significantly influence on the quality of oil extracted from *Morinda citrifolia* seeds.

Article Information

Received: 24 June 2025
Revised: 08 July 2025
Accepted: 09 July 2025
Published: 20 July 2025

Academic Editor

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Keywords

Evaluation, extraction method, physicochemical quality, noni oil, *Morinda citrifolia*.

1. Introduction

Noni (*Morinda citrifolia*) is a plant that grows to a height of 3 to 10 m and is available in the pantropics. The noni fruit and leaves have traditionally been used in the diet of people in the Pacific Islands, as well as in South and Southeast Asia. Although the fruit is edible, its taste has been described as similar to spoiled cheese. More recently, the fruit has been used to produce dietary supplements with therapeutic properties [1]. Furthermore, noni fruit is reported to

be used not only to lower blood sugar levels but also in the treatment of certain diseases such as Mycobacterium tuberculosis, arthritis, diabetes and hypertension. [2, 3]. In addition, noni fruits can be consumed in various forms, such as fermented or pasteurized juices, powders and noni capsules [4, 5]. Moreover, the noni seeds are an important source of chemical components, including crude fiber (55.45 and 28.70 g/100 g), phenols, carotenoids, tannins,



vitamin C and flavonoids [5-7]. Chemical and nutritional analyses of *M. citrifolia* have revealed that there are more than 200 phytochemicals such as acids, alcohols, phenols, saccharides, anthraquinones, carotenoids, esters, triterpenoids, flavonoids, glycosides, lactones, iridoids, ketones, lactones, lignans, nucleosides, triterpenides, sterols, and aromatic compounds with bioactive properties [8]. This characteristic may be affected by climate, genetics, geographical distribution, and fruit maturity stage [7]. It also has antioxidant power attributable to the presence of flavonoids due to a combination of chelating activities, free radical scavenging and inhibition of oxidases and other enzymes [9]. Consequently it is used as a food ingredient [10]. Furthermore, noni seeds contain valuable quality oil. It was reported that this oil is rich in linoleic acid that is similar to sunflower oil [3]. The chemical quality of this oil can be affected by several factors, therefore, studies have focused on evaluating the quality of oils extracted from noni seeds. In this context, a study by Codex [11] to evaluate the usefulness of noni seed oil in terms of nutritional quality and safety, the results showed that the average contents of β -sitosterol, campesterol, stigmasterol and α -tocopherol in noni seed oil were 4310, 2195, 2020 and 382 mg kg⁻¹, respectively. No evidence of acute oral toxicity was found in this oil. The authors concluded that noni seeds could be a useful new source of vegetable oil. Furthermore, noni oil has utility in other fields, for example, [12] noted that not only is noni oil a source of long-chain polyunsaturated fatty acids, but also they have a natural surfactant property for deinking flotation because the lipophilic part of their structure has a potential for high intermolecular interactions with oil-based ink. Indeed, noni seed oil has antioxidant and regenerative properties. It is used topically to treat inflammatory skin conditions and joint pain associated with arthritis and rheumatism. Moreover, it is an effective remedy in cases of fungal, viral, bacterial or parasitic infections. Its application relieves itching, irritation and even burns. Despite the above-listed usefulness, no study has focused on evaluating the effects of extraction methods on the quality of noni oils. Thus, this study is the first time, to evaluate the effects of extraction methods on the physicochemical quality of noni oil produced in

Senegal.

2. Material and methods

2.1. Materials used

The materials used in this experiment included seeds from the ripe fruit of *Morinda citrifolia* L., and various laboratory equipment (incubator, analytical balance, desiccator, Soxhlet apparatus, funnels, filter papers, beakers, volumetric pipettes, pycnometer, spatula, burettes, etc.). All chemicals were of analytical grade and included heptane, chloroform, acetic acid, hydrochloric acid, potassium thiosulfate solution, Wiis's reagent, starch paste, potassium iodide, etc.

2.2. Sample preparation

In this study, ripe fruits of *Morinda citrifolia* L. (noni) were used. A total of 1000 g of noni was harvested in Thiès at the Karamoko station. The ripe fruits were placed in a bag and quickly transported to the analysis and testing laboratory of the Polytechnic Higher School (ESP) of Cheick Anta Diop University in Dakar (Senegal). They were washed with bleach (2.6%) and dried at room temperature for 1 h. The dried fruits were placed in a hermetically sealed container for two weeks to induce fermentation. Subsequently, the fermented fruits were placed in a basin (Fig. 1a) and manually crushed in water (Fig. 1b).



Figure 1. Treatment of (a) fermented and (b) crushed fermented fruits.

The mixture was then filter using a sieve to recover the seeds which were dried on a table away from light for 2 weeks (Fig. 2a). After drying, the seeds were ground using an electric mixer and the powder was stored (Fig. 2b).

2.3. Noni Oil Extraction Technique

Two oil extraction techniques were used, namely, maceration and Soxhlet extraction method.

2.3.1. Noni oil extraction method by maceration

The oil extraction by maceration is a process that involves allowing a solid to remain in a cold liquid to

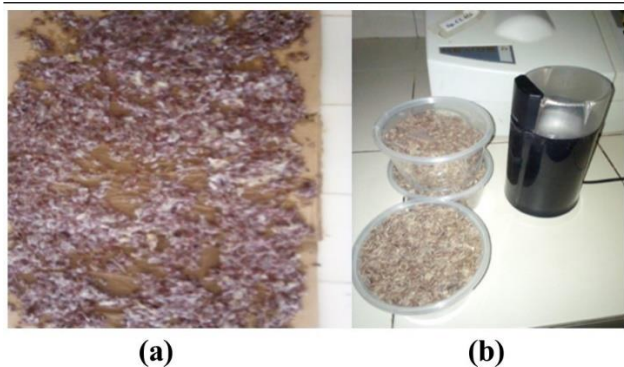


Figure 2. Treatment of (a) spread seeds and (b) seeds in jars.

extract soluble compounds or to absorb the liquid to obtain its fragrance or flavor, to preserve it, or to decompose it. The principle of this method is based on immersing the matrix in a solvent at room temperature to extract soluble components. The maceration method was carried out as follows: 50 g of noni seed powder, wrapped in filter paper, was added to 350 mL of heptane in a 500 mL beaker. The maceration was carried out for 3 h at room temperature, while stirring. Subsequently, the macerate was filtered and the solvent was separated from the residue using a rotary evaporator. The residue was then dried in an oven at 102 °C for 1 h and then cooled in a desiccator for 15 min. Finally, the mass of the bottle containing oil was measured.

2.3.2. Oil extraction by the Soxhlet method

The oil extracted by the Soxhlet method by using the Soxhlet apparatus (Behr Laboratechnik GmbH). The principle of this method is to extract fat by organic solvents (hexane, isopropanol, heptane, chloroform, etc.). In our study, 95% heptane was used. The technique consisted of drying the flask in an oven set at 105 °C for 1 h and cooling in a desiccator for 15 min. The empty flask was weighed and its mass was noted. A total of 20 g of noni seed powder was weighed on a piece of Joseph paper and placed in a cartridge to which 100 mL of heptane was added. The flask was stopped with the Soxhlet and the latter with a water condenser. This system was placed on a heating mantle and turned on. The tap for refrigeration was then opened. After 3 h of extraction, the heating mantle was turned off to cool the heptane and removed the cartridge. Distillation was initiated to recover heptane in a bottle. Finally, the flask was dried in an oven at 102 °C for 2 h followed by weighing and calculation of the oil extraction yield.

2.4. Calculating oil extraction yield

The oil extraction yield was calculated by dividing the mass of oil obtained after extraction by the mass of the noni seed powder used for extraction. The yield, expressed as a percentage, was calculated using the following formula.

$$RE = \frac{MHE}{MPGU} \times 100$$

RE: Extraction yield.

MHE: Mass of extracted oil.

MPGU: Mass of seed powder used.

2.5. Measurement of physicochemical parameters

2.5.1. Moisture content measurement

The AFNOR method (NF T60-201) was used to determine the moisture content of the extracted noni oil. The principle of this method is based on heating the oil to 103 °C until complete elimination of water and determination of the mass loss. To do this, 2 g of oil was weighed in a previously tared flask, (M1) and weighed again (M1). Place the flask containing the test sample was placed in an oven previously set to 103 °C. After 2 h of drying, the flask was placed in the desiccator for cooling, followed by weighing. Then, reintroduce the flask into the oven for one hour and weighed after cooling; if the difference between the two weighings was less than or equal to 5 mg, the operation was considered complete and the weighing procedure was continued (M2). All analyses were carried out in triplicate.

2.5.2. Refractive index measurement

The refractive index was measured according to the French standard (NF T60-212). The measurement was carried out at 25 °C using the refractometer (Exacta-Optech, Mod-RMT, München, Germany). Indeed, the measurement was carried out by depositing an extracted drop on the measuring cell of the device. The value of the refractive index of the oil was obtained by reading on a graduated scale.

2.5.3. Acid Index and acidity measurement

The acid number of a fatty substance corresponds to the number of milligrams of potassium hydroxide required to neutralize the free acidity of one gram of a fatty substance. The French standard (NF T60-204) was used to measure the acid numbers. This index is determined by dissolving a test sample in a mixture of solvents and titrating the free fatty acids present using

a 0.1N sodium hydroxide solution. Thus, 10 g of the test samples were weighed in Erlenmeyer flasks, to which 50 ml of ether/alcohol solution was added. Then, titrate by stirring with the 0.1N potassium hydroxide solution in the presence of phenolphthalein, until the pink color changes, which persists for a few seconds.

2.5.4. Measurement of peroxide value

The peroxide value of a fatty substance is the number of active micrograms of peroxide contained in one gram of product and oxidized potassium iodide with the release of iodine. For the analysis of our samples, the method of the French standard (NF T60-220) was used to determine the peroxide value. The technique consisted of placing approximately 2 g of oil in an Erlenmeyer flask to which 10 mL of chloroform was added, followed by 15 mL of acetic acid and 1 mL of saturated potassium iodide, and stirring for 1 min away from light. Then, 75 mL of distilled water and 1 mL of starch paste (as an indicator) were added. Titrate the released iodine with a sodium thiosulfate solution (0.01 N).

2.5.5. Saponification index measurement

The saponification index (Is) was determined according to the NF T60-206 standard method. The principle consists of titrating the excess potassium hydroxide with a hydrochloric acid solution (0.5 N), after heating at reflux. Therefore, a mass of two (2) grams of noni seed oil was weighed, to the nearest 0.001 g, in a 250 mL conical flask. To this test sample, 25 mL of an ethanolic potassium hydroxide solution (0.5 N) was added and the mixture was brought to a gentle boil for one (1) hour. Afterward, a few drops of phenolphthalein solution were added to the hot soapy solution. The titration was carried out with a hydrochloric acid solution (0.5 N).

2.5.6. Iodine index measurement

The iodine index (Ii) was determined according to the French standard (reference NF T60-203). It corresponds to the mass of iodine (I₂) fixed on the unsaturations of the fatty acids of 100 g of a fatty substance and it makes it possible to determine the degree of unsaturation of a vegetable oil. The principle is based on the determination of the excess Wijs reagent transformed into iodine after the addition of potassium iodide and water, by titrating

the liberated iodine with a thiosulfate solution (Na₂S₂O₃). Thus, 0.20 g of oil was weighed, to the nearest 0.001 g, in a 500 mL flask to which 15 mL of carbon tetrachloride was added. After dissolution, 25 mL of Wijs's reagent (0.1 N) was added to the same flask, stirred gently and placed for one hour in a dark place at a temperature of around 25 °C. Subsequently, 20 mL of potassium iodide (mass concentration of 100 g.L⁻¹) and 150 mL of distilled water were added to the solution. In the presence of a few drops of starch paste (0.01 g.L⁻¹), titration was carried out with sodium thiosulfate solution (0.1 N) until a the color change was observed.

2.6. Statistical analysis of data

Statistical analyses were performed using STATA version 15.1 software. Means, standard deviations and percentages were calculated for qualitative variables. The Student t-test was used to compare means and the Chi2 test was used to compare percentages. Differences were considered for statistically significant at $p \leq 0.05$.

3. Results and discussion

3.1. Recovery of *Morinda citrifolia* L. seeds

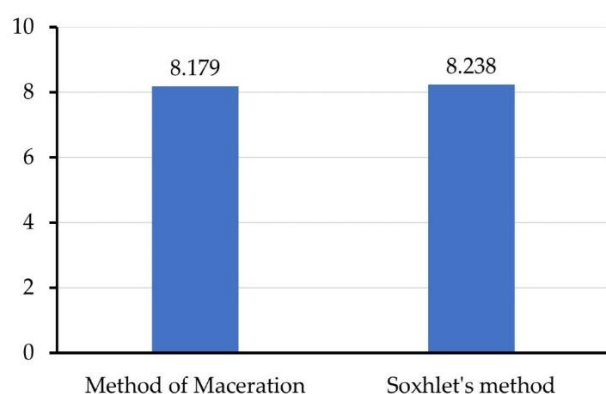
The seed recovery yields are presented in Table 1. From this table, it is evident that the average recovery yield was $6.635 \pm 0.841\%$. This rate is similar to that reported by [13], who obtained a yield of $6.77 \pm 2.39\%$. Recently, [14] reported about 15.1% oil extraction in Malaysian noni seeds with petroleum ether as the extraction medium. The possible explanation for this variation in yields reported in different studies could be due to several parameters, such as cultivar origin, temperature and climate [14].

3.2. Extraction yield of oil from noni seeds

The extraction yields of the noni seed oils are presented in Fig. 3. The yields obtained by the maceration method and Soxhlet methods were 8.179% and 8.238%, respectively. The results showed that the oil extraction yield by the maceration method is significantly lower than that obtained by the Soxhlet method. Furthermore, the high percentage of oil in noni seed makes it a potential source of industrial oil. The extraction yields in our study are comparable to those of commercially important cottonseed oil (18-20%), goji seed oil (16.4%) and bitter melon seed oil

Table 1. Extraction yield of *Morinda citrifolia* seeds.

Quantity of fruit (g)	Quantity of seeds obtained (g)	Seed extraction yields (%)	Average seed extraction yields (%)
600 g	43.38	7.23	6.635 ± 0.841
400 g	24.17	6.04	

**Figure 3.** Results of noni seed oil extraction by maceration and Soxhlet method.

(20.2%) [14, 15]. Our extraction yield is close to that found by [16], who obtained 6.4% extraction yield from *Nigella sativa* L. seeds (nigella seeds). These variations could be attributed to fruit variety, climatic conditions during the harvest period and soil nature. These differences could be attributed to the extraction methods used. Furthermore, our results are lower than those reported by [14], who obtained a noni seed oil extraction rate of 12.5%. The authors added that oils are generally extracted using screw press, solvent extraction and supercritical carbon dioxide extraction methods. These differences could be attributed to the extraction method, as reported by [14], who indicated that among these methods, solvent extraction is more efficient, but there are safety concerns as organic solvents are toxic [15]. These values are higher than those reported by [17], who found a yield of 8% using hexane as a solvent for extracting oil from noni seeds. On the other hand, our results are significantly lower than those reported by [18], who obtained an extraction yield of *Griffonia simplicifolia* oil by the Soxhlet method of $28.40 \pm 1.20\%$. The results showed that the extraction yield varied depending on the method and solvent used.

3.3. Measurement of physicochemical parameters

3.3.1. Moisture content measurement

Fig. 4a shows the moisture values measured in noni

oils extracted by maceration and Soxhlet methods, with results of 0.318% and 0.075%, respectively.

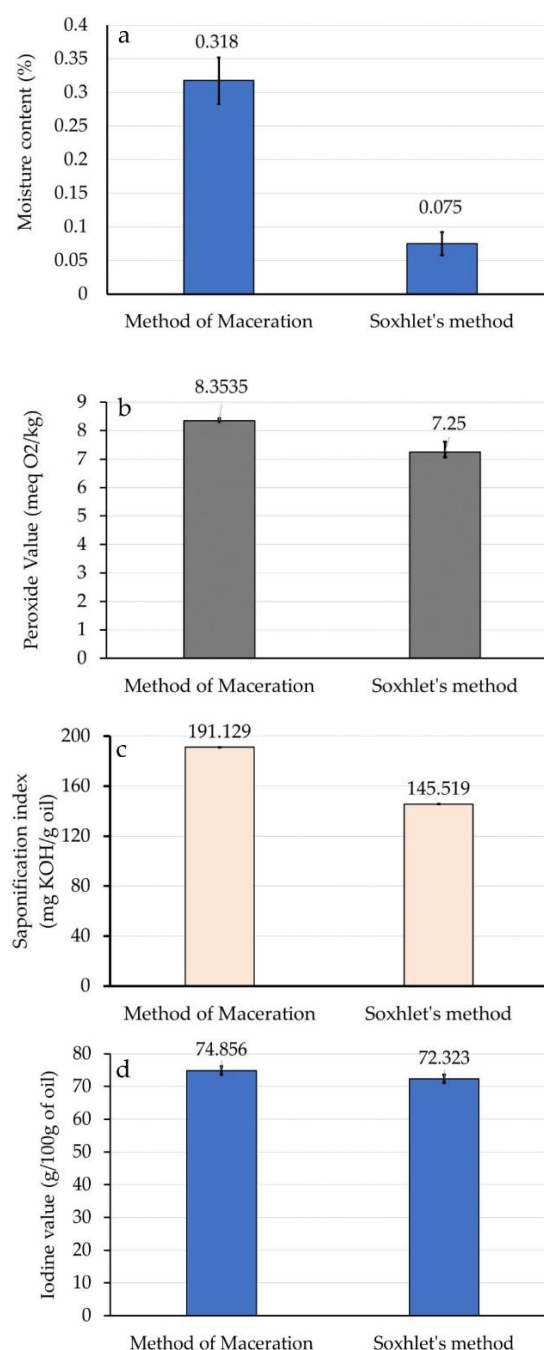
**Figure 4.** Results of the physicochemical parameters (a) moisture, (b) peroxide value, (c) saponification value, and (d) iodine value determined on noni oil.

Table 2. Results of determination of some physicochemical parameters on noni oil.

Extraction methods	Physicochemical parameters		
	Refractive index	Acid number (KOH/10 g of oil)	Acidity (%)
Method of Maceration	1.464 ± 0.001	4.9415 ± 0.002	2.4835 ± 0.007
Soxhlet's method	1.464 ± 0.001	7.9405 ± 0.168	3.991 ± 0.084

The numbers in the table indicate the means plus or minus standard deviations.

The oil obtained by maceration had a higher moisture content than that extracted by the Soxhlet method. Moreover, all these values are higher than that of reported [19] data on soybean oil production and physicochemical analyses, which was 0.336%. This difference could be attributed, on the one hand, to the technique used, and on the other hand, to the nature of the raw material used. On the other hand, the observed moisture content was lower than that of reported [18], value of $7.88 \pm 1.83\%$ for *Griffonia simplicifolia* seed oil. These differences can be attributed to the drying techniques, the nature of the seeds used for extraction and the extraction method chosen. In short, noni oil obtained by maceration has a very low water content, typically less than 0.2%, which corresponds to the standards of pure vegetable oils and guarantees good conservation of the oil, as a higher water content of the oils would promote microbial growth and rancidity [20]. In a similar study conducted on oils extracted from *Moringa oleifera* seeds, a moisture content of 7.9% was obtained [21], a slightly similar value (7.78%) was obtained by [22] in *Moringa oleifera* oils. These different results show that the moisture content of the oils varies from one product to another, and from one sample to another.

3.3.2. Refractive index

The refractive index values were determined for two oils obtained by maceration and the Soxhlet method are presented in Table 2. The RI value was found at 1.464 for both methods (maceration and Soxhlet). This value is close to the reported [23] by the evaluation of the quality of peanut oil, found at 1.471. Furthermore, our result is similar to that found by [24] which was 1.472, in *Nigella sativa* L oil. On the other hand, our result is slightly higher than that of natural oil which is 1.420 [25]. Furthermore, the Codex Alimentarius in 1993, established a normative RI value between 1.467 and 1.470 for oils. Based on this standard, we concluded that our samples were edible. Furthermore,

the results obtained by [26] indicate that the refractive index varies between (1.466 and 1.470) which indicates that all the oils analyzed can be considered as non-pure and drying because they do not comply with the NF T 60-212 standard where the refractive index of non-drying oils varies between 1.468 and 1.470.

3.3.3. Acid value

The acidity of the noni oils is presented in Table 1. In our study, the acid numbers measured by maceration and Soxhlet methods (Table 1) were 4.941 mg KOH/10 g of oil and 7.94 mg KOH/10 g of oil, respectively. These results indicate that the acid number of the oil extracted by Soxhlet is higher than that of the oil obtained by maceration. However, these values exceed those reported by [26], which ranged from 0.93 to 2.80 mg KOH/10 g of oil, as well as the result of 0.81 mg KOH/10 g of oil found by [27] in their research on sunflower oil. In addition, our results are also higher than those of [25], who found an acid number of 1.4026 mg KOH/10 g of oil in their studies on the extraction, characterization, and identification of chemical compounds in a natural oil. Our acid numbers also exceed the range reported by [28], which ranged from 0.22 to 1.39 in their studies on the physicochemical parameters of cottonseed oils produced in the CMDT area of Mali. These differences could be attributed to the seed harvesting technique, duration of seed storage, and the oil extraction method. In the present study, the best results were obtained using the Soxhlet method. Additionally, [29] indicates that a high acidity index in the oil has shown that the oil may not be suitable for use in cooking (edibility), but may be useful for the production of paints, liquid soaps, shampoos and other industrial applications. The results found in this study were higher than the value indicated by [30], namely 4.0 mg KOH/g for virgin fats and oils.

3.3.4. Acidity measurement

As mentioned in Table 2, the results concerning the acidity of the oils extracted by maceration and by the Soxhlet method are 2.484% and 3.991%, respectively. These data indicated that the acidity of the oil obtained by the Soxhlet method is higher than that obtained by maceration. Moreover, all these values are higher than that of reported data [19] on soybean oil production, which was 0.54%. They also exceeded the results obtained in their research [31] on sunflower oil, whose values ranged from 0.21% to 0.36%. Our results are between the values of 1.77% and 5.83% which based on the reported data [32], in their studies on the physicochemical characterization of olive oils produced in traditional oil mills in the Chaouia region of Morocco. This difference could be due to the fermentation of the fruits during the harvesting of the seeds and the extraction technique. Furthermore, Okandza et al. obtained an acidity value of 1.40 ± 0.09 mg KOH/g for Patuá oil [33]. The authors noted that the Brazilian National Health Surveillance Agency (ANVISA) indicates that this index is one of the most important quality control parameters for oils. The ANVISA has set standards for unrefined cold-pressed oils at a maximum value of 4.0 mg KOH/g of oil. Based on this standard, we can conclude that our samples were of acceptable quality. However, for extra virgin oil, the oleic acidity must be 0.8% and for virgin oils, it must be less than 2.0% [34]. Based on these benchmarks, it should be said that the two oils extracted by maceration and Soxhlet are neither virgin nor extra virgin. However, these results show that the Soxhlet method yields higher quality oils compared to maceration.

3.3.5. Peroxide value

The peroxide values (PV) obtained in our study were 8.353 meq O₂/kg and 7.25 meq O₂/kg for the oils obtained by maceration and Soxhlet extraction, respectively (Fig. 4b). These results show that the peroxide value of the oil obtained by maceration was higher than that obtained by the Soxhlet method. These results show that maceration contributed more to the oxidation of the oils than the Soxhlet method. However, our results are higher than those reported by Nkeiruka et al. [31], who indicated that the peroxide value of sunflower oil ranged between 1.66 and 2.17 meq active oxygen/kg. However, the peroxide value

of the oil obtained by the Soxhlet method is close to the reported data [35], who showed that olive oil has a peroxide value of 7.33 meq of active oxygen/kg. Our results were found lower than those of the reported data [25], which was 32 meq of active oxygen/kg, in their studies on the extraction, characterization and identification of chemical compounds from natural oil. Comparing the results of the peroxide values of our oils with the reported values [36] which peroxide values of conventional oils should be less than 10 meq of oxygen/kg, therefore, we conclude that this result is in agreement with our results. Furthermore, our results were below the regulatory thresholds stipulated by Brazilian legislation (< 15 mEq/kg) [37]. This compliance with the standards is attributable to appropriate storage practices and minimal exposure to oxygen and light, mitigating the risk of peroxidation, which is common in vegetable oils [33]. On the other hand, the peroxide value is a measure of the peroxides in the oil and helps determine the degree of spoilage. The standard peroxide value for non-rancid edible oils should be well below 10 meq/kg [39], for the edible oils from *Pinus pinea* seed extraction and physicochemical characterization, which was 6.42 meq of oxygen/kg of oil. This variation is due to the storage conditions and oil extraction techniques.

3.3.6. Saponification values

The saponification value is a measure of oxidation during storage and indicates deterioration of oils [40]. The saponification values are shown in Fig. 4c. The results obtained by the maceration and Soxhlet method were 191.124 mg KOH/g oil and 145.509 mg KOH/g oil, respectively. This indicates that the saponification value of the oil extracted by maceration is higher than that of the oil obtained by Soxhlet extraction. In addition, the saponification value of the oil obtained by maceration was comparable to those of sunflower oil (190 (mg/KOH/g of oil)), olive oil (186 (mg/KOH/g of oil)), and soybean oil (191 (mg/KOH/g of oil)) [41]. This value is also higher than that of reported value [42], which was 188 mg KOH/g by the extraction method and based on the physicochemical characterization of *Moringa oleifera* seed oil. On the other hand, the saponification index of the oil extracted by the Soxhlet method was lower than that

of reported value [42]. In contrast, the saponification index of the oil extracted by these two methods was lower than the reported value (117.7 mg/KOH/g of oil) [40] for *Indigofera zollingeriana* oil extracted by cold pressing. In addition, our results are also lower than those of [24], who found an index of 214.863 mg KOH/g of oil in their work on the physicochemical characterization and biological evaluation of *Nigella sativa* L. oil. Additional report [27] was found to be at 194.73 mg KOH/g for the saponification index of sunflower oil. In a study conducted by West et al [43] on sunflower oil, an index of 197.14 mg KOH/g was observed, which is higher than our results. This difference could be attributed to the length of time the oil is exposed to high temperatures during extraction, as well as the nature of the seeds used for extraction. Comparing our results with the acceptability value interval set by the FAO (170.0–181.0 mg/KOH/g of oil), it appears that our samples do not comply with this normative regulation [40].

3.3.7. Iodine value

The iodine values of oils extracted by maceration and the Soxhlet method shown in Fig. 4d. According to this figure, the iodine value of the oil extracted by maceration (74.871 g/100g) was higher than that obtained by the Soxhlet method (72.333 g/100 g of oil). These results are lower than those reported by [17], who obtained an index of 86.25 g/100 g of oil extracted from noni seeds using hexane as a solvent.

Our results are also higher than those of a study [42], who found an index of 65.41 g/100 g of oil in the oil extracted from *Moringa oleifera* seeds. In addition, our iodine values are higher than those reported by [18], who found a value of 13.38 ± 1.59 g/100 g of oil in their research on various physicochemical parameters and analysis of mineral elements, chlorophyll pigments and carotenoids of *Griffonia simplicifolia* seed oil. On the other hand, our results are lower than those of report [44], who found an index of 111 ± 0.11 g/100 g of oil extracted from *Sesamum indicum* L. The variation observed in these results could be attributed to the oxidation of unsaturated fatty acids as well as the nature of the seeds used for oil extraction. The iodine value makes it possible to evaluate the average degree of unsaturation of an oil, the higher the iodine value the greater the number of C=C double bonds. Thus, it

is expressed in grams of iodine absorbed per 100 g of lipid and is directly proportional to the degree of unsaturation (number of double bonds) and inversely proportional to the melting point of the lipids. This value allows us to quantify the number of double bonds present in the oil, which indicates its sensitivity to oxidation. The value obtained was also within the range of the established standard (104-120) [38]. Based on this range, we can conclude that the analyzed samples were below this standard, probably due to the extraction methods used.

4. Conclusion

This study demonstrates that maceration and Soxhlet extraction methods significantly influence the physicochemical quality of oil extracted from *Morinda citrifolia* seeds. This study revealed that although the extraction yields by maceration (8.179 %) and Soxhlet (8.238 %) are similar, the analysed parameters such as moisture, acid peroxide, iodine and saponification values were significantly different between the two methods. For example, the oil extracted by maceration had a moisture content of 0.318 % compared to 0.075 % for that obtained by Soxhlet extraction. The acidity indices were 2.483 % for maceration and 3.991 % for Soxhlet, while the peroxide indices were 8.353 meqO₂/kg for maceration and 7.250 meqO₂/kg for Soxhlet extraction. In addition, the iodine index obtained is higher in the oils obtained by maceration (74.871 g/100 g) compared to the Soxhlet method which was 72.333 g/100 g. For the saponification index, an opposite trend was observed, since 145.509 mg KOH/g was found for maceration against 191.124 mg KOH/g for Soxhlet. In summary, the results obtained in the present study allow us to conclude that the oil extracted by the Soxhlet method presents more favorable values in terms of quality, which suggests that it could be preferable to obtain a better-quality oil. Despite the interesting results obtained in this study, it is possible to carry out more in-depth techniques, such as chromatography, mid-infrared spectroscopy and nuclear magnetic resonance (NMR) on larger samples to characterize the oils extracted from *Morinda citrifolia*.

Authors' contributions

Collected field data, conducted laboratory experiments, and wrote the first draft of the manuscript, S.K.; Participated in establishing the methodology, in the preparation of the original version, correcting, and editing the manuscript, M.S.; Participate in the validation of the subject, correction of the manuscript, and supervision, N.A.N.; Participate in the validation of the methodology, correction of the manuscript L.N.; Participates in the preparation of the original version, and in proofreading, M.D.

Acknowledgments

The authors thank the Guinean Ministry of Higher Education, Scientific Research and Innovation for funding this project and the Higher Institute of Veterinary Sciences and Medicine (ISSMV) of Dalaba for its contribution to the realization of this research.

Funding

This study was funded by the 1000 PhD and 5000 Master's Program of the Ministry of Higher Education, Scientific Research and Innovation of the Republic of Guinea.

Availability of data and materials

All data will be made available on request according to the journal policy.

Conflict of interest

The authors have no competing interests to declare that are relevant to the content of this article.

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