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# Biological and Cosmetic Potential of Essential and Vegetable Oils from Citrus Aurantium L.: A Sustainable Valorization Approach

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***Abstract***
*The study is thus oriented toward evaluating the chemical characteristics and biological activities of Citrus aurantium L., including potential cosmetic applications, as well as its essential and vegetable oils. The oil is obtained from the peel by hydrodistillation, with a yield that varies with the period of recult: 1.30 ± 0.30% in December and 0.76 ± 0.20% in January. GC-MS analysis results show that the composition contains monoterpenes as major components, with limonene being the main compound, 91.80% (December sample) to 62.84% (January sample)*
*The cold-pressed seed oil was high in polyunsaturated fatty acids, mainly linoleic acid (40.58%), as well as palmitic and oleic acids. Both physicochemical and organoleptic analyses attested to the high quality of the oils and their suitability for cosmetic use.*
*Biologically, the essential oil exhibited considerable antifungal activity against Candida spp. with a dose-dependent effect and maximum inhibition zone of 29.0 ± 1.0 mm at 1 ml concentration; meanwhile, the vegetable oil displayed marked antioxidant activity assessed by DPPH test, characterised by a significant increase in radical scavenging activity with increasing concentration ($p \leq 0.05$).*
*Natural lip scrubs were formulated using extracted oils and a finely sieved cake. The formulations showed good physicochemical stability, pH compatible with the lip area, and excellent skin tolerance. Sensory evaluation of 30 volunteers revealed a preference for the formulation enriched with vegetable oil, which provided better hydration and comfort during application and produced soft, uniform exfoliation due to the cake's mechanical action.*
*Overall, these results confirm the strong biological and cosmetic potential of Citrus aurantium L. and underscore its value for sustainable use in developing innovative natural cosmetic products.*
***Keywords***: *Citrus aurantium L.; essential oil; limonene; vegetable oil; biological activity; cosmetics.*

## 1. INTRODUCTION

Plant resources have long served as the primary source of natural substances for health, food, and cosmetics [1] . Growing demand for natural, safe, and environmentally benign products has spurred renewed interest in aromatic and medicinal plants, particularly those that yield pharmaceutically valuable bioactive compounds [2]. In this context, *Citrus* species play a vital role due to their wide geographical distribution, traditional uses, and, most importantly, the diversity of secondary metabolites discovered within these fruits or expressed by them [3].

*Citrus aurantium* L. (bitter orange) is widely cultivated in the Mediterranean region. Different parts of the plant are known for their chemical richness. In particular, peels and seeds are highly useful matrices for extracting natural oils with high biological and functional potential [4]. Monoterpenes, particularly limonene, generally predominate in the essential oil obtained from the peel. The seed contains a vegetable oil rich in fatty acids [5].

The antifungal and antioxidant properties of *Citrus* essential oils are well recorded. Primarily, terpene compounds, such as limonene, are responsible for these properties [6]. It is well known that environmental factors can vary the yield and chemical composition of oils. These environmental factors include the harvest period, climatic conditions, and the fruit's maturity stage [4].

Simultaneously, there is growing interest in the cosmetic industry for vegetable oils of *Citrus* seed origin because they contain high levels of polyunsaturated fatty acids. Particularly emphasised is linoleic acid.

Linoleic acid plays a crucial role in the function of the skin barrier, influencing transepidermal water loss and elasticity [7]. However, herein lies an irony: as much as there should be rising interest based on all accounts summarised above, *Citrus aurantium* L. seeds remain largely unused. They are clearly an excellent source of natural ingredients for dermo-cosmetic formulations.

With the increasing trend toward natural and sustainable cosmetic products, this approach is innovative and environmentally friendly, as it simultaneously valorises essential and vegetable oils from *Citrus aurantium* L. By-products, which can be transformed into high-value-added ingredients for cosmetic applications.

This study aims to contribute to the valorisation of the essential and vegetable oils of *Citrus aurantium* L. harvested in Moudjebara (Djelfa, Algeria) by evaluating their chemical and biological properties and their potential cosmetic applications. Specifically, this study aims to:

- Evaluate the yield of essential oil by month of harvest;
- Determine, by GC–MS analysis, the chemical composition of essential and vegetable oils;
- Determine their physicochemical and organoleptic characteristics.
- Test the antifungal activity of the essential oil and the antioxidant activity of the vegetable oil.
- Lip scrubs will be formulated and evaluated in terms of stability, tolerance, and sensory acceptability.

## 2. MATERIALS AND METHODS

### 2.1. Climatic Conditions

The climate station data used in this study are from Djelfa. The Moudjebara area lies approximately 30 km north of Djelfa, which is the study area. Average temperatures for January and February 2024 are 7°C and 8°C, respectively, while cumulative precipitation totals are 10 mm and 13 mm, respectively.

### 2.2 Plant material

Fruits of *Citrus aurantium* L. were picked fully ripe and healthy by hand randomly in the region of Moudjebara. After harvesting, the fruits were washed, and the peels were carefully separated and cut into uniform pieces. The peels were then dried in the shade at room temperature for 15-20 days.

The seeds were also collected, washed with distilled water to remove impurities, and dried under the same conditions as the peels. After drying, all samples were packed in paper bags and stored in a dark, moisture-free location until used for extraction.

### 2.3 Extraction and Determination of Essential Oil Yield

Essential oil of *Citrus aurantium* L. was hydrodistilled from 100 g dried peel using a Clevenger-type apparatus. Distillation was performed for three hours after the onset of boiling. The collected oil was separated from the distillate, dried over anhydrous sodium sulfate to remove residual moisture content, and stored in amber glass bottles at 4-5°C until further analysis.

Dry matter content was first determined to calculate the essential oil yield. A powder sample was dried at 105°C for 24 hours. Dry matter (DM) is defined as the difference between the total weight of aluminium foil plus dried sample (Ps) and the weight of aluminium foil alone (A). The essential oil yield is expressed in percentage (%) as a ratio between the mass of essential oil obtained (M) over the mass of dry plant material ($M_0$), using the following formula:

Yield (%) = $(M / M_0) \times 100$.

### 2.4 Physicochemical and Organoleptic Characteristics of the Essential Oil

Several parameters were used in determining the physicochemical characteristics of the essential oil. Its pH was measured after dispersing it in distilled water. The refractive index at 20°C was determined using a refractometer, while its relative density was evaluated by the pycnometric method at 20°C. An organoleptic analysis aimed at determining and assessing sensory properties of appearance and color, odor, fluidity or viscosity, as well as volatility, was established for this sample of essential oil.

### 2.5 Extraction and Physicochemical Characterization of Vegetable Oil

*Citrus aurantium* L. seeds were cold-pressed with a screw press (Vie Bio, Blida) to express vegetable oil. No chemical solvents were used; only mechanical extraction was used to conserve the bioactive compounds and the oil's natural properties. The yield is expressed in millilitres per kilogram of seeds (mL/kg). The residual cake after extraction was carefully collected, dried, and finely ground for later use as a cosmetic ingredient, particularly as a natural exfoliating agent in a lip scrub formulation.

The determination of physicochemical characteristics used to evaluate the quality and suitability of the oil for cosmetic applications included relative density at 20°C, refractive index, colour and clarity, viscosity at room temperature, and acid value.

### 2.6 Chemical Composition Analysis of Essential Oils by GC–MS

Chromatographic analyses of the essential oil and vegetable oil were performed on a gas chromatograph with electronic pressure control (Chrompack CP 9002) fitted with a fused silica capillary column (DB-5), 30 m long, 0.25 mm internal diameter, and 0.25 µm film thickness. The system also comprises a flame ionisation detector (FID) supplied with a hydrogen/air gas mixture, operating at 280°C, plus a split/splitless injector set at 250°C. Nitrogen was used as the carrier gas, flowing at 1mL/min.

Injection was performed in split mode with a 1:50 split ratio and a split flow rate of 66 mL/min. The column temperature program was set from 50 ˚C (held for 3 min) to 250 ˚C at 2 ˚C/min, followed by a final hold at 250 ˚C for 10 min.

### 2.7 Evaluation of Antifungal Activity of *Citrus aurantium* L. Essential Oil

Antifungal activity of *Citrus aurantium* L. essential oil was assessed by its ability to inhibit the growth of *Candida* spp. Strain. The direct contact method on a solid medium has been used to determine the minimum inhibitory concentration (MIC) of antifungal potency.

Three millilitres of essential oil were mixed with three millilitres of dimethyl sulfoxide (DMSO) to form a homogeneous stock solution. From this stock solution, different volumes (1 mL, 0.50 mL, and 0.25 mL) were placed into wells previously made in MH agar plates inoculated with the test strain *Candida* spp. The petri dishes were incubated at 37 °C for 18 h. After incubation, antifungal activity was assessed by visual observation of fungal growth around the wells. The appearance of inhibition zones indicated the antifungal effect of the essential oil tested.

### 2.8 Antioxidant Activity (DPPH Assay)

The method described by Chen et al. (2004) was adopted to determine the antioxidant activity of *Citrus aurantium* L. vegetable oil using the DPPH (2,2-diphenyl-1-picrylhydrazyl) free radical scavenging assay. The samples were first dissolved in ethanol to make a stock solution containing 20 µg/2 mL and then serially diluted to achieve concentrations of 10,20,40,60,80 ,100 ,200 and 300 µg/mL.

The test was conducted by mixing 4 mL of DPPH solution and 1 mL of essential oil at different concentrations in dry test tubes. The mixture was left standing at room temperature for 30 minutes, protected from light, after which absorbance was measured at 517 nm using a UV-Visible spectrophotometer.

A blank was prepared by replacing the sample with ethanol, while a standard antioxidant (ascorbic acid or BHT) was used as a positive control. The decrease in absorbance was used to evaluate antioxidant activity, expressed as a percentage of DPPH radical inhibition according to the following equation:

Inhibition (%)= $(A_0 - A_s / A_0) \times 100$

Where $A_0$ is the absorbance of the control and $A_s$ is the absorbance of the tested sample.

All experiments were repeated three times. Results have been reported as mean ± standard deviation. Statistical analysis was conducted to examine the effect of concentration on antioxidant activity. There was a gradual increase in the percentage inhibition with increasing concentration, indicating a significant free radical-scavenging capacity of the oil under study.

### 2.9 Formulation, Physicochemical Characterization, and Sensory Evaluation of Lip scrubs

Two lip scrub formulations were developed. (Table 01) In the first formulation, which contains no vegetable oil, Vitamin E is added as a preservative; in the second formulation, *Citrus aurantium* L. vegetable oil is used both for its function and as a preservative. The ingredients in both cases are melted over a double boiler and then homogenised. The finely ground cake, previously sieved, is added at 40-45°C, after being pre-dispersed in a small quantity of coconut oil, into suitable containers.

Physicochemical analyses included pH, melting point, and stability at 4°C, 25°C, and 40°C. Sensory analysis was also performed, in which 30 respondents volunteered to try both products over several days before rating the following attributes: texture, spreadability or ease of application on lips, moisturising effect or perceived effectiveness as a lip scrub product, smell, perceived effectiveness (as a lip scrub product), and tolerance.

Table 01: Lip scrub formulations.

| Formulation 1 | Formulation 2 |
|---|---|
| 243.4 g petroleum jelly | 243.4 g petroleum jelly |
| 10 g beeswax | 10 g beeswax |
| 11 g glycerin | 11 g glycerin |
| 13 g castor oil | 13 g castor oil |
| 30 g coconut oil | 30 g coconut oil |
| 1.6 g bitter orange essential oil | 1.6 g bitter orange essential oil |
| Vitamin E | 14 g bitter orange seed vegetable oil |
| 6.6 g press cake | 6.6 g press cake |

### 2.10 Statistical Analysis

Data are presented as mean ± standard deviation. Means were compared using analysis of variance (ANOVA), and results were considered statistically significant if $p < 0.05$.

## 3. RESULTS

### 3.1 Evaluation of Essential Oil Yield

A statistical analysis was conducted to determine the effect of harvest month (December and January) on the essential oil yield obtained by hydrodistillation of *Citrus aurantium* L. peel. Results show that the difference is not statistically significant at the 5% significance level ($p>0.05$). The average yields were 1.30 ± 0.30% in December and 0.76 ± 0.20% in January (Figure 01), indicating a decrease from one month to the next.

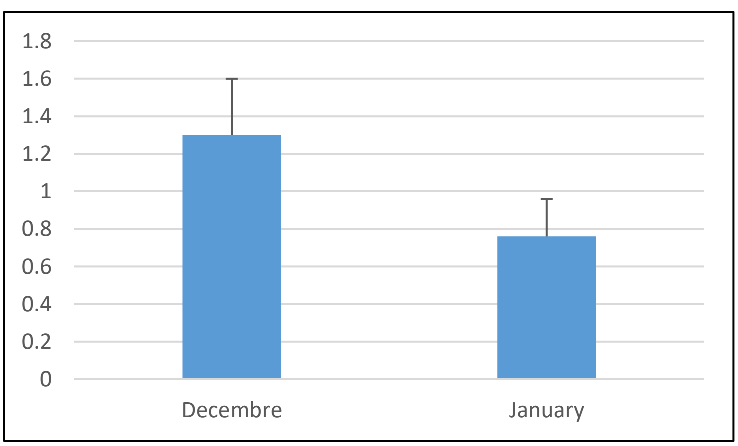


Figure 01: Essential oil yield

### 3.2 GC–MS Composition of the Essential Oil

According to the results of GC-MS analysis in Table 02, the oil extracted from Citrus *aurantium* L. was highly rich in monoterpenes. The significant component identified was limonene, which accounted for 91.80% (in December) to 62.84%, as shown by total composition values recorded across different months. Other minor components were also present, most likely belonging to typical *Citrus* fruit monoterpenes and their homologues or derivatives [8].

Table 02: Major compounds (%) of the essential oil from bitter orange peel.

| | December | | | January | | |
|---|---|---|---|---|---|---|
| **Constituents** | **Pic N°** | **Tr (mn)** | **Echant. D.1.285 1.849** | **Pic N°** | **Tr (mn)** | **Echant. J 1.287 31.96 C** |
| *α-Thujene* | | | | 01 | 11.79 | 0.04% |
| *α-pinene* | 01 | 11.91 | 0.62% | 02 | 12.18 | 1.65% |
| Camphene | | | | 03 | 12.95 | 0.04% |
| Sabinene | 02 | 14.20 | 0.10% | 04 | 14.49 | 0.72% |
| *bêta-pinene* | 03 | 14.35 | 0.10% | 05 | 14.70 | 3.53% |
| *Bêta -Myrcene* | 04 | 15.34 | 1.77% | 06 | 15.75 | 5.83% |
| α-Phellandrene | 05 | 16.08 | 0.14% | 07 | 16.03 | 0.14% |
| α-Terpinene | | | | 08 | 16.45 | 2.28% |
| *P.Cymene* | | | | 09 | 17.20 | 0.28% |
| *Limonene* | 06 | 18.11 | 91.80% | 10 | 18.70 | 62.84% |
| δ-Terpinene | | | | 11 | 19.47 | 0.75% |
| γ-terpinene | 07 | 20.91 | 0.71% | 12 | 20.09 | 0.25% |
| α-Terpinolene | 08 | 21.99 | 0.30% | 13 | 21.24 | 0.42% |
| *linalol* | 09 | 22.80 | 1.48% | 14 | 23.18 | 1.31% |
| *Terpinen 4-ol* | | | | 15 | 28.53 | 1.05% |
| *Alpha-Tepeneol* | 10 | 29.17 | 0.61% | 16 | 29.57 | 1.52% |
| Nerol | 11 | 31.95 | 0.09% | 17 | 31.45 | 0.21% |
| Citral | 12 | 33.82 | 0.47% | 18 | 32.26 | 0.13% |
| Geranylacetate | 13 | 42.54 | 0.40% | 19 | 43.31 | 1.78% |
| Acetate de linalyl | | | | 20 | 45.11 | 2.78% |
| Béta-Caryophyllene | 14 | 45.86 | 0.07% | 21 | 47.62 | 3.61% |
| a.Bergamotene | | | | 22 | 49.01 | 0.72% |
| Humulene | | | | 23 | 49.89 | 0.61% |
| *Bêta-Bisabolene* | 15 | 48.71 | 0.07% | 24 | 51.87 | 0.76% |

### 3.3 GC–MS Composition of the Vegetable Oil

The results of fatty acid composition from the oil extracted from the seeds of *Citrus aurantium* L. harvested in December are shown in Table 03. The analysis revealed fifteen compounds with different contents depending on the identified fatty acids. Linoleic acid was the most abundant component, accounting for 40.58%, followed by palmitic and oleic acids, which accounted for 27.17% and 23.02%, respectively.

The general analysis of fatty acid fractions shows a higher content of polyunsaturated fatty acids (44.75%), followed by saturated fatty acids (30.66%) and monounsaturated fatty acids (23.75%). This makes vegetable oil from *Citrus aurantium* L. both nutritionally and functionally sound, making it particularly suitable for use in cosmetics.

Table 03: Fatty acid composition and content (%) of bitter orange seed oil.

| **Fatty acid** | **Designation** | **Echant.** |
|---|---|---|
| *C14 :0* | *Myristic acid* | *0.051 %* |
| *C16 :0* | *Palmitic acid* | ***27.17 %*** |

| | | |
|---|---|---|
| *C16 :1ω7* | *Palmitoleic acid* | *0.50 %* |
| *C17 :0* | *Margaric acid* | *0.20 %* |
| *C17.1* | *Margaroleic acid* | *0.12 %* |
| *C18 :0* | *Stearic acid* | *2.82 %* |
| *C18 : 1ω9* | *Oleic acid* | ***23.02 %*** |
| *C18 : 2ω6* | *Linoleic acid* | ***40.58 %*** |
| *C18 : 3ω3* | *Linolenic acid* | *4.16 %* |
| *C20 :0* | *Arachidonic acid* | *0.27 %* |
| *C20 :1* | *Gadoleic acid* | *0.10 %* |
| *C22 :0* | *Behenic acid* | *0.06 %* |
| *C24 :0* | *Lignoceric acid* | *0.09 %* |
| ***Saturated fatty acids*** | | ***30.66 %*** |
| ***Monounsaturated fatty acids*** | | ***23.75 %*** |
| ***Polyunsaturated fatty acids*** | | ***44.75 %*** |

**3 .4 Organoleptic and Physico-chemical Profile of *Citrus aurantium* L. Essential Oil**

The essential oil is a clear liquid of pale yellow to yellow-orange colour with a fresh, tangy aroma typical of *Citrus* fruits and slightly bitter notes characteristic of extracts rich in limonene. It has a fluid, non-viscous texture. The rapid evaporation when exposed to air at room temperature indicates a high monoterpene content.

From a physicochemical perspective, the essential oil exhibited a slightly acidic pH (5.5-5.6), consistent with values reported for *Citrus* essential oils [9]. The refractive index was measured to be 1.471, and the relative density was 0.84 at 20°C.

**3.5 Yield and Physicochemical Characteristics of the Vegetable Oil**

Cold pressing *Citrus aurantium* L. seeds collected over 2 months yielded 100 mL of oil from 400 g of seeds (250 mL/kg extraction yield). This is a good yield for mechanical extraction without solvents and also shows the high lipid content of bitter orange seeds.

The physicochemical characteristics of the vegetable oil are carefully evaluated to determine its quality and potential for use in cosmetic formulations. The results obtained for the two months of harvesting are as follows:

- Relative density at 20 °C: The measured density was 0.82, which is consistent with the density of *Citrus*-derived vegetable oils [10].
- Refractive index: The refractive index ranged from 1.470 to 1.471, similar to the values reported for Moroccan bitter orange [11].
- Colour and clarity: At room temperature, its colour ranged from pale yellow to yellow orange; it was clear, thus indicating purity as well as proper filtration.
- Viscosity at room temperature: Low viscosity was measured.
- Acid value: Acid value was 1.5 mg KOH/g.

**3.6 Antifungal Effects of *Citrus aurantium* L. Essential Oil**

The results of the antifungal activity test of *Citrus aurantium* L. essential oil against *Candida* spp. Showed that the inhibition was dependent on its concentration (Table 04). At a 1 ml dose, it showed maximum antifungal activity, with a mean zone of inhibition of 29.0 ± 1.0. A slight decrease in fungal growth inhibition was observed at 0.50 and 0.25 ml concentrations, with mean values of 17.5 ± 0.5 and 13.5 ± 0.5, respectively.

There is a highly significant difference between the effects of different concentrations of essential oil on the growth of *Candida* spp. ($p < 0.001$). Therefore, the results clearly demonstrate a dose-response relationship, whereby increasing the concentration yields significantly higher antifungal activity.

Table 4: Antibacterial activity of the essential oil of *Citrus aurantium* L.

| **Concentration Essential oil (mL)** | **Inhibition du *Candida spp*** |
|---|---|
| 1 mL | 29,0 ± 1,0 |
| 0,50 mL | 17,5 ± 0,5 |
| 0,250 mL | 13,5 ± 0,5 |

### 3.7 Antioxidant Activity of the Vegetable Oil

Increases in measured absorbance and reducing power were observed with increasing concentration, reaching high reducing power, indicating its antioxidant activity. The results of the percentage radical scavenging activity indicate that *Citrus aurantium* L. vegetable oil has a considerable capacity ($p \leq 0.05$) to neutralise free radicals.

The percentage inhibition increased steadily with concentration, following a trend similar to that of the reference standard (Figure 02).

ANOVA revealed a significant difference among the tested concentrations. This statistically significant variation indicates that increasing oil concentration results in a measurable increase in antioxidant activity. These results confirm the strong antioxidant potential of the vegetable oil studied.

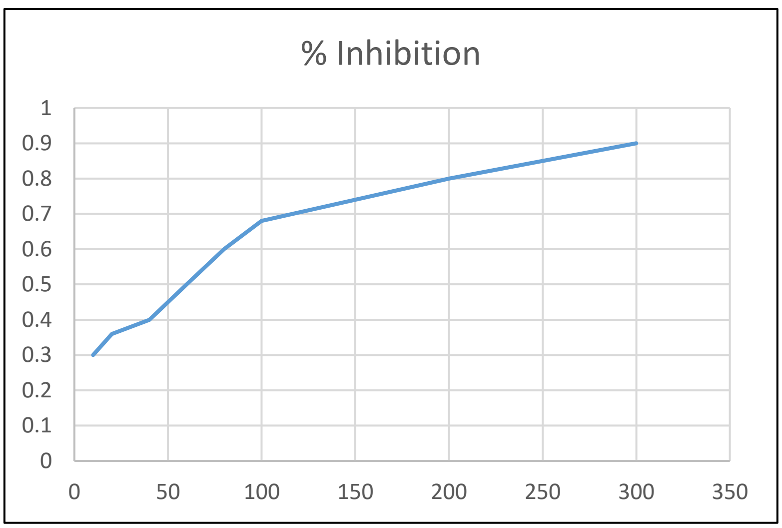


Figure 02: Percentage inhibition of the DPPH free radical.

### 3.8 Physicochemical Properties of Lip Scrubs

The pH values ranged between 5.5 and 6.2, close to the physiological pH of the lip area. The melting points ranged from 53°C to 58°C, indicating proper consistency and good resistance to softening at room temperature and at slightly higher temperatures. There was no phase separation or change in colour or odour when stored at 4°C, 25°C, and even 40°C, demonstrating the formulations' good thermal stability.

### 3.9 Sensory Evaluation

Thirty volunteers participated in a sensory evaluation of the tolerance and effectiveness of both lip scrub formulations. Parameters include texture, spreadability, moisturising effect, comfort during application, odour, perceived effectiveness, skin tolerance and exfoliating effect. No adverse reactions were reported by any participants who used either product. None reported irritation or discomfort while using both products, indicating excellent skin tolerance.

Both formulations exhibited a mild exfoliating effect, attributable to the finely sieved cake, which slowly removed dead cells from the lips' surface without irritation. This uniform, non-aggressive exfoliation, as perceived by most volunteers, helped improve the softness and appearance of the lips after use.

In Formulation 2, both as a preservative and a functional ingredient, *Citrus aurantium* L. vegetable oil was consistently preferred by the volunteers. Its exfoliating effect is perceived as more effective and better tolerated, likely due to the synergy between the cake's mechanical action and the emollient and protective properties of the vegetable oil. The texture is perceived as softer and more melt-in-the-mouth, making it easy to apply smoothly on the lips and providing instant, long-lasting moisturisation with increased comfort during application. The scent is perceived as natural and pleasant, thereby improving product acceptability. Perceived effectiveness after several days' use showed faster reduction in signs of dryness and discomfort associated with chapped lips.

On the other hand, formulation one, which is stabilised only with vitamin E, also had a satisfactory effect, though slightly less pronounced. Its thicker texture made it harder to spread, which may have partially limited its exfoliating action and the comfort of application. The moisturising effect and perceived comfort were considered less intense. These differences can be explained by the lack of vegetable oil, an ingredient high in lipophilic and emollient compounds that enhance skin hydration, protection, and regeneration [13].

## 4. DISCUSSION

The study on the essential oils and vegetable oil of *Citrus aurantium* L. from Djelfa, supported by chemical analysis, physicochemical parameters, biological assays, and formulation tests followed by a sensory evaluation, provides scientific evidence of its significant potential for both biological and cosmetic use.

There was an apparent monthly variation in essential oil yield, with higher values in December than in January. This variation was not significant at 5% level. Still, the observed decline is significant and likely reflects the effects of factors such as climatic conditions and the biochemical composition of *Citrus aurantium* L. bark. This general observation has also been reported for other *Citrus* species [4].

GC-MS analysis of the essential oil showed a high limonene content, particularly in December. Limonene is one of the major monoterpenes usually present in *Citrus* essential oils [14]. Antimicrobial, antifungal, and antioxidant effects have been reported in the literature and are consistent with the biological activities evidenced in this study [15] [6]. The oil is also rich in monoterpenes, which confer organoleptic properties, imparting a fresh, tangy aroma [16].

The yield from cold pressing is satisfactory, once again confirming the lipid-richness of bitter orange seeds. GC-MS analysis revealed a high proportion of polyunsaturated fatty acids, dominated by linoleic acid, followed by palmitic and oleic acids. Modern cosmetic literature clearly establishes the role of linoleic and other essential fatty acids in skin barrier function, hydration, and regeneration through their beneficial influence on epidermal lipid composition, ceramide synthesis, and skin barrier function [7].

The organoleptic and physicochemical characteristics of *Citrus aurantium* L. essential oil conform to typical traits of this group of oils: clear in appearance, ranging from pale yellow to yellow-orange, and possessing a fresh, tangy odour characteristic of *Citrus* oils. Its low concentration provides good fluidity and ease of application, both of which are necessary in cosmetic formulations [17].

The slightly acidic pH (5.5–5.6), refractive index of 1.470-1.471, and relative density are values very similar to those reported for *Citrus aurantium* L. and other *Citrus* essential oils, thereby also supporting the stability and authenticity of the oil studied (Anwar et al., 2008). A combination of these parameters, with a low acidity index, indicates minimal alteration in this essential oil, making it highly suitable for cosmetic applications where stability, fluidity, and sensory acceptability are key factors [13].

The good stability and minimal degradation it displays can be inferred from its physicochemical characteristics: low viscosity, colour ranging from pale yellow to orange-yellow, clarity, a refractive index compatible with *Citrus* oils, and an acid value of 1.5 mg KOH/g (<2). These are the most preferred properties in cosmetic formulations, as they ensure high quality and safety for the intended user, while also enhancing shelf life.

The antifungal activity of the essential oil against *Candida* spp. was concentration-dependent, with maximum inhibition at 1 mL. Statistical analysis also revealed a highly significant dose-response relationship, supporting

the potential of this essential oil as a natural antifungal agent. Similar results were obtained in other studies, in which *Citrus* essential oils inhibited certain pathogenic fungi and bacteria because most contain high levels of limonene [15].
At the same time, the DPPH test showed that the vegetable oil has a high antioxidant activity. The real potential for neutralising free radicals is evidenced by a steady increase in percentage inhibition with increasing concentration, which may be due to unsaturated fatty acids and other bioactive compounds present. Well documented is also the fact that *Citrus* oils and their derivatives possess antioxidant activity, mainly due to the presence of antioxidant compounds, such as polyphenols and carotenoids, within the *Citrus* matrix [18] [19].
The physicochemical evaluation of the formulated lip scrubs revealed good thermal stability and compatibility with the physiological pH of the lip area, essential criteria for cosmetic acceptability [20]. Formulation trials and sensory evaluation confirmed the functional benefits of *Citrus aurantium* L. vegetable oil. The enriched formulation was clearly preferred by volunteers, both sensorially and functionally, offering improved hydration, superior application comfort, excellent skin tolerance, and gentle, even exfoliation. These observations are consistent with the emollient effects attributed to lipophilic compounds present in vegetable oils [21].
The observed exfoliating effect is directly attributable to the incorporation of finely sieved press cake, which acts as a gentle mechanical exfoliant, promoting the removal of dead skin cells without causing irritation. This type of mechanical exfoliation is well tolerated when applied in a controlled manner to sensitive areas such as the lips. The synergistic combination of the press cake and the lipids in the vegetable oil promotes deep hydration and improves lip texture, which is consistent with the use of essential fatty acids in cosmetics to strengthen the skin barrier function and improve skin softness and suppleness [7].
In summary, this study demonstrates that *Citrus aurantium* L. is a promising plant resource for the development of innovative natural cosmetic products, combining biological efficacy, safety of use, and excellent sensory acceptability.

## 5. CONCLUSION

This work provides relevant scientific data concerning the valorization of essential and vegetable oils from *Citrus aurantium* L. harvested in the Djelfa region. Through an approach combining chemical, physicochemical, biological, and applied analyses, this study highlights the multifunctional potential of this species, which remains underutilized in the cosmetics field.
The study of essential oil yield revealed a notable variation depending on the month of harvest, with higher values recorded in December than in January. Although this variation was not statistically significant, it suggests an influence of seasonal factors on the biosynthesis and accumulation of volatile compounds in the peels. These results underscore the importance of the harvest time for optimizing the quality and composition of the essential oil.
GC-MS analysis of the essential oil revealed a composition largely dominated by limonene, the high content of which—particularly in December—confirms the typical character of *Citrus* essential oils and largely explains the observed biological properties. At the same time, the vegetable oil extracted from the seeds has distinguished itself by its richness in polyunsaturated fatty acids, particularly linoleic acid, which gives it a notable interest for dermo-cosmetic applications.
From a biological perspective, the essential oil demonstrated significant antifungal activity against *Candida* spp., with a clearly concentration-dependent effect, while the vegetable oil exhibited marked antioxidant activity, as demonstrated by the DPPH assay. These results confirm the bioactive potential of *Citrus aurantium* L. oils and their ability to act as natural protective agents.
The incorporation of these oils into cosmetic formulations, particularly lip scrubs, demonstrated their practical applicability. The formulated products exhibited good physicochemical stability and a pH compatible with the lip area. Sensory evaluation revealed improved acceptability of the formulation enriched with vegetable oil, offering increased hydration, superior application comfort, and gentle, even exfoliation, attributable to the mechanical action of the finely sieved press cake.
In summary, the results confirm that *Citrus aurantium* L. represents a promising plant resource for the development of innovative natural cosmetic products. This study opens up interesting perspectives for the

sustainable valorization of *Citrus* by-products and encourages further research to deepen the understanding of biological mechanisms, optimize formulations and evaluate long-term effectiveness under real-world conditions.

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