UFSM

CIÊNCIA e NATURA

ISSN 2179-460X
OPEN ACCESS

Ci. e Nat., Santa Maria, v. 47, e88050, 2025 • https://doi.org/10.5902/2179460X88050
Submitted: 06/28/2024 • Approved: 07/15/2025 • Published: 10/24/2025

**Chemistry**

# Anti-inflammatory and antioxidant potential of silver nanoparticles synthesized using *Cinnamomum verum* essential oil nanoemulsion

## Potencial anti-inflamatório e antioxidante de nanopartículas de prata sintetizadas utilizando a nanoemulsão do óleo essencial de *Cinnamomum verum*

**Antonio Felipe Correa Lucas[I], Thamires de Jesus Teles Ribeiro[I], Américo Pinheiro Neto[I], Victor Elias Mouchrek Filho[I], Gustavo Oliveira Everton[I,II]**

[I] Federal University of Maranhão, São Luis, MA, Brazil
[II] Federal Institute of Maranhão, São Luis, MA, Brazil

## ABSTRACT

This study evaluated the chemical profile, antioxidant, and anti-inflammatory activity, in an unprecedented way, of silver nanoparticles (AgNPs) synthesized from the essential oil nanoemulsion (NEO) of *Cinnamomum verum*. For essential oil extraction (EO), the hydrodistillation technique was used, and the chemical constituents were identified by Gas Chromatography Coupled to Mass Spectrometry (GC-MS). The nanoemulsions were prepared using the phase inversion method, and the synthesis of the AgNPs was performed by the Ag reduction method of $AgNO_3$ using NEO. The AgNPs were characterized in terms of chemical profile by UV-Vis Spectrophotometry and particle size by DLS. Antioxidant activity was evaluated using the ABTS radical discoloration method and anti-inflammatory activity by protein denaturation. The majority constituent of the EO was trans-Cinnamaldehyde (82.12%). The maximum SPR band was centered at 420 nm indicanting the characteristic peak of AgNPs. The best $IC_{50}$ 59.46 mg $L^{-1}$ for antioxidant activity was obtained for AgNP pH 10. The best $IC_{50}$ for anti-inflammatory activity was 0.3183 mg $mL^{-1}$. This study brought in an unprecedented way results for AgNPs of C. verum, demonstrating to be efficient in improving the activities tested in this study, and also demonstrating the effect of pH in these formulations.

**Keywords:** Antioxidant; Trans-Cinnamaldehyde; Formulation

**RESUMO**

Este estudo avaliou o perfil químico, a atividade antioxidante e anti-inflamatória, de forma inédita, de nanopartículas de prata (AgNPs) sintetizadas a partir da nanoemulsão de óleo essencial de *Cinnamomum verum* (NEO). Para a extração de óleo essencial (OE), utilizou-se a técnica de hidrodestilação e os constituintes químicos foram identificados por GC-MS. A atividade antioxidante foi avaliada pelo método de descoloração dos radicais ABTS e a atividade anti-inflamatória por desnaturação proteica. O constituinte majoritário do OE foi o trans-Cinamaldeído (82,12%). A banda máxima de RPS foi centrada em 420 nm, indicando o pico característico das AgNPs. A menor $IC_{50}$ 59,46 mg $L^{-1}$ para atividade antioxidante foi obtida para AgNP pH 10. A $IC_{50}$ que demonstrou o melhor resultado para atividade anti-inflamatória foi a do pH 9 com 0,3183 mg $mL^{-1}$. Este estudo trouxe de forma inédita resultados para AgNPs de C. verum, mostrando-se eficiente na melhoria das atividades testadas neste estudo, demonstrando também o efeito d o pH sobre essas formulações.

**Palavras-chave**: Antioxidante; Trans-Cinamaldeído; Formulação

## 1 INTRODUCTION

Over the years, researchers focus on metallic nanoparticles due to large surface area, low melting point and good optical, catalytic, electrical and thermal properties. These distinct properties of metal nanoparticles create exploitation in the industrial area, such as food, agriculture, space, cosmetics, medical and chemical aspects of everyday use (Tan et al., 2002; Liu et al., 2004).

In recent decades, nanotechnology has gained more recognition due to its unique properties associated with the size distribution and morphology of nanoparticles. Nanotechnology was a comprehensive term that covers many areas of research that deal with nanometer-covered objects such as chemistry, physics, biology, engineering and other scientific aspects of nanotechnology (Bar et al., Tuutijärvi et al. 2009).

Metallic nanoparticles have nanotechnological applications in various fields, such as diagnostic medicine (high-efficiency biosensors, imaging); pharmacy (drug delivery systems, cosmetics); food and textile industry (packaging and clothing with antimicrobial properties); energy (solar panels); bioremediation, among others (Kumar & Yadav 2009; Thirumurugan & Dhanaraju 2011). Nanoparticles with 1 to 100 nm have great impact in the field of chemistry, optics, batteries, physics, environmental remediation,

drug administration and medicine. Nanoparticles exhibit huge structures that create a different approach in the catalytic, physical, chemical and medicinal properties of materials than in mass (Yu et al., 2007; Rassaei et al., 2008; Tuutijärvi et al., 2010).

Plants are particularly safe for bioreduction as they are readily available, inexpensive and scalable (Mathew et al., Rostami-Vartooni et al., 2006; Nasrollahzadeh et al., 2016). The compounds that are extracted from natural products can be used in different areas, especially in the pharmaceutical and food industries. Research has shown the importance of extracts and essential oils in the production of new antibiotics and in the fight against various pathologies (Vanin, 2014; Venturoso et al., 2010; Guimarães, 2017).

The choice of green synthesis is related to the ability of plants to act in the reduction, protection and stabilization of metallic nanoparticles due to their secondary metabolites, organic compounds elaborated by plants, to adapt species and survive. The reduction of silver particles in the nanometric scale infers changes in their properties, resulting in an increase in the ratio between the surface area and volume, which potentiate their characteristics in relation to their macrometric form (Helou, 2018).

Its great oxidizing activity becomes very interesting for green synthesis. Since then, silver synthesis becomes feasible to reduce silver ions, for metallic silver through bioreduction. All this benefit can be used in the form of dressings with action in the control of the bacterial population during the preparation of the bed of a wound in the healing process (Wilkinson et al., 2011).

Silver nanoparticles (AgNPs) possess unique properties, such as a high surface area, stability, and antimicrobial activity. Furthermore, these particles demonstrate high stability and an excellent capacity for adsorbing pollutants in contaminated waters, owing to their strong interaction with aromatic compounds. These characteristics make AgNPs highly promising for applications in nanomedicine and environmental remediation (Gandlevskiy et al., 2025).

Medicinal plants are of great importance in traditional medicine, in which, to a large share, the antioxidant activity of plant-derived compounds is considered responsible for the cure of numerous diseases. *Cinnamomum verum* consists of many polyphenolic compounds with antioxidant activity.

The genus *Cinnamomum* belongs to the family Lauraceae, many of which are used as spices and flavorings (Jakhetia et al. 2010). There are two main varieties of cinnamon: Ceylon or True Cinnamon (*Cinnamomum verum*), which is grown in Sri Lanka and Southern India, and cassia (*Cinnamom aromaticum Ness*), which is grown in China, Indonesia and Vietnam (Shan et al., 2007; Ranasinghe et al., 2012).

However there are differences in this, in relation to the variety and parts of the plant. Studies with essential oils extracted from the barks of *Cinnamomum verum* showed 60 to 80% of cinnamaldehyde and 2% of eugenol, while in leaves the composition of eugenol is higher, around 60 to 75% (Lima et al., 2005; Trajano et al., 2010; Vangalapati et al., 2012). Essential oils extracted from the variety *Cinnamomum aromaticum Ness* showed the presence of 80 to 90% cinnamaldehyde with little or no eugenol (Shan et al. 2007). Thus, this study aimed to evaluate the chemical, antioxidant and anti-inflammatory activity of silver nanoparticles synthesized from the nanoemulsion of the essential oil of *Cinnamomum verum*.

## 2 METHODOLOGY

### 2.1 Collection of plant material

The barks of *Cinnamomum verum* used in this study were obtained in August 2022, from the federally certified distributor - Produtos Naturais Muniz LTDA (CNAE 4729-6/99). After collection, the plant species were transported to the Laboratory for Research and Application of Essential Oils (LOEPAV/UFMA), where the leaves were weighed, crushed and stored for the extraction of essential oil from the plant.

## 2.2 Extraction of essential oils

For the extraction of the essential oil (EO), the hydrodistillation technique was performed with a Clevenger glass extractor coupled to a round bottom flask coupled to a heating blanket as a source of heat. 100g of each plant material were used, previously dried in a FANEM 520 convective air oven at 45°C, adding distilled water (1:10). Hydrodistillation was performed at 100°C for 3 h and the EO extract was collected. The EO was dried by percolation with anhydrous sodium sulfate ($Na_2SO_4$) and centrifuged. These operations were carried out in triplicate and the samples were stored in amber glass ampoules under refrigeration at 4°C. Subsequently submitted to analyses.

## 2.3 Chemical Profile

The identification of chemical constituents was performed by gas chromatography coupled to mass spectrometry (GC-MS), using a QP 2010 Plus model equipment (Shimadzu Corporation, Kyoto, Japan) operating with a fused silica capillary column (30 m × 0. 25 mm). with a DB-5 bonded phase (film thickness, 0.25 µm).

Helium was used as a carrier gas with a flow rate of 1.0 mL $min^{-1}$. The injector and detector temperatures were 220 and 240 °C, respectively. The injection volume of the sample was 0.5 µL, diluted in hexane (1%) and injection volume partition ratio (split) of 1:100. The temperature ramp started at 60 °C, with an increase at a rate of 3°C $min^{-1}$ to 240°C, followed by an increase of 10°C $min^{-1}$ until reaching 300°C, with the final temperature maintained for 7 min. The column pressure was around 71.0 kPa.

The mass spectrometer was operated with an ionization potential of 70 eV and an ion source temperature of 200°C. Mass analysis was performed in full scan mode, ranging from 45 to 500 Da, with a sweep speed of 1000 Da $s^{-1}$ and a scan interval of 0.5 fragments $s^{-1}$. Data were obtained and processed using Lab software Solutions LC/GC Workstation 2.72 (Shimadzu, Kyoto, Japan).

The retention index of the compounds was calculated in relation to a homologous series of n-alkanes ($nC_9$ – $nC_{18}$), using the Van den equation Dool and Kratz (Van Den Dool

& Kratz, 1963). The identification of the compounds was carried out by comparing the calculated retention indices with those described in the literature (Adams et al., 2007). Comparisons of the mass spectra obtained with those existing in the FFNSC 1.2, NIST107 and NIST21 libraries were also performed.

Quantitative analysis was performed by gas chromatography with flame ionization detector (GC-FID), using equipment model GC-2010 (Shimadzu Corporation, Kyoto, Japan), with identical experimental conditions to those used in the qualitative analysis, except for the temperature of the detector, which was 300°C. The relative percentages of each constituent were obtained by the area normalization method.

### 2.4 Preparation of the nanoemulsions

The preparation of the nanoemulsions was carried out according to the adapted methodologies described by Sugumar et al. (2014), Kubitschek et al. (2014) and Rodrigues et al. (2014).

The EO concentration (5% v / v) were fixed for the formulation. The required amounts of each constituent of the oil phase (oil + Tween20) were heated to 65 ± 5°C. The aqueous phase was heated separately to 65 ± 5°C, added gently and mixed with the oil phase, providing a primary formulation, by the phase inversion method. Final homogenization was achieved using a magnetic stirrer, in which the formulation remained in constant agitation at 6000 rpm, until the temperature was reduced to 25 ºC ± 2 ºC.

To prove stability, of the formulated nanoemulsions were subjected to different stress tests according to the methodology described by Shafiq et al., (2007). They were evaluated for phase separation by centrifugation. The heating-cooling cycle was carried out keeping the formulated nanoemulsions at 40 and 4°C, alternating each temperature for 48 h. The cycle was repeated three times. This was done to check the stability of the nanoemulsion at variable temperatures. The freeze-thaw stress was carried out by maintaining the nanoemulsions alternatively at -21 and 25°C for 48 h at each temperature. The cycle was repeated twice. The experiment was carried out in triplicate.

## 2.5 Formulation and characterization of nanoparticles

The synthesis of silver nanoparticles was performed according to the methodology adapted by Sena et al. (2019) and Vilas, Philip and Mathew (2014). To obtain them, a solution of silver nitrate ($AgNO_3$, 1 mmol $L^{-1}$) was prepared in distilled water. For synthesis, the pH of the $AgNO_3$ solution was adjusted to 10 with sodium hydroxide solution (NaOH 0.1 mol $L^{-1}$). For each condition tested, 10 mL of the $AgNO_3$ solution with the respective corrected pH was heated to 50 °C in heating plate and constant magnetic agitation. For the addition of the essential oil, a solution of 1000 mg $L^{-1}$, diluted in acetone 1% for the concentrations of 4-167 mg $L^{-1}$, added in a volume of 5 mL in the reaction system, was prepared, totaling a total volume of 15 mL. After mixing, the solution remained homogenized for 10 min and then incubated for a period of 24 hours at room temperature.

Spectroscopic analyses in the UV-Vis region were performed on spectrophotometer in length of 1000-320 nm. 3 mL of each sample was pipetted in quartz bucket with optical path of 10 mm at room temperature.

The readings of the size and distribution of the nanoparticles in the colloides were performed by the technique of dynamic light scattering - DLS, which evaluates the hydrodynamic ray using a zetasizer System Nano ZS90 (Malvern Instruments, UK), following the methodology described by Sena et al. (2019). Measurements were performed under the following conditions: laser wavelength (He-Ne) at 633 nm, fixed scattering angle at 173º and temperature of 25ºC and normal resolution mode. The readings were performed with a polystyrene bucket (DTS0012) using a volume of 1.5 mL with a dilution factor of 3x.

## 2.6 Total Phenolics

The determination of the total phenolic compounds of the crossed essential oil and nanoemulsion was performed by the Folin-Ciocalteu spectrophotometric method (Waterhouse, 2012). 5 mg of samples diluted in 1 mL of ethanol were used. To this solution, 7 mL of distilled water, 800 µL of Folin-Ciocalteu reagent and 2.0 mL of 20% sodium carbonate were added. After two hours, the reading was performed in a

UV-VIS spectrophotometer at a length of 760 nm. The standard curve was expressed in milligrams equivalent to grams (mg TAE $g^{-1}$) of tannic acid.

### 2.7 Antioxidant activity by elimination of ABTS radicals

A determination of antioxidant activity by the ABTS method [2,2-azinobis-(3-ethylbenzothiazolin-6-sulphonic)], was adapted according to the methodology suggested by Re et al. (1999). From the concentrations of essential oils and silver nanoparticles (5 to 100 mg/L) in ethanol, the reaction mixture with ABTS radical cation was prepared. In a dark environment, an aliquot of 100 µL of each concentration of samples containing 3.0 mL of abts radical cation was transferred and after 6 minutes the absorbance of the reaction mixture was read in spectrophotometer at a length of 730 nm. The analyses were performed in triplicate. The elimination of ABTS radicals was expressed as a percentage and the Efficient Concentration 50% ($EC_{50}$/$IC_{50}$) and 90% ($EC_{90}$/$IC_{90}$) capable of inhibiting 50% and 90%, respectively, of elimination was expressed in mg/L.

### 2.8 Anti-inflammatory activity by albumin protein denaturation

The anti-inflammatory activity was evaluated by the albumin protein denaturation method by thermal degradation (Padmanabhan & Jangle, 2012).

The reaction mixture (4000 µL) consisted of 1000 µL of different concentrations of essential oils and e silver nanoparticles (100-500 mg/L) diluted in PBS and 3000 µL of a solution to 10% albumin diluted in PBS and incubated at (37±1) °C for 15 minutes. Denaturation was induced by keeping the reaction mixture at 70°C in a water bath for 10 minutes. After cooling, absorbance was measured at 660 nm in a UV/VIS spectrophotometer. Inhibition of protein denaturation was expressed in percentage and the 50% Efficient Concentration ($EC_{50}$ / $IC_{50}$) capable of inhibiting 50% of denaturation was expressed in mg/L.

# 3 RESULTS AND DISCUSSION

## 3.1 Chemical profile

Table 1 presents the chemical composition of the EO *C. verum* extracted in this study.

Table 1 – Chemical composition of the essential oil of *Cinnamomum verum*

| Compound | IR[b] | IR[c] | (%)[a] |
|---|---|---|---|
| Benzaldehyde | 962 | 962 | 0,46 |
| Camphene | 986 | 986 | 0,38 |
| Acetophenone | 1032 | 1032 | 0,96 |
| β-Pinene | 1043 | 1042 | 0,28 |
| Linalool | 1091 | 1090 | 0,91 |
| Camphor | 1147 | 1146 | 0,67 |
| Benzenepropanal | 1163 | 1162 | 0,74 |
| Borneol | 1165 | 1164 | 0,3 |
| cis-Cinnamaldehyde | 1214 | 1215 | 2,22 |
| Decanal | 1222 | 1223 | 0,29 |
| Decane,3-ethyl-3-methyl- | 1228 | 1229 | 0,34 |
| trans-Cinnamaldehyde | 1234 | 1235 | 82,12 |
| Dodecane, 2,6,10-trimethyl- | 1319 | 1320 | 0,31 |
| Copaene | 1379 | 1379 | 2,26 |
| Geranyl acetate | 1393 | 1393 | 0,38 |
| α-Famesene | 1420 | 1420 | 0,46 |
| Cinnamyl acetate | 1438 | 1438 | 0,91 |
| α-Muurolene | 1440 | 1440 | 1,01 |
| α-Guaiene | 1489 | 1489 | 3,51 |
| Naphthalene, 1,2,3,4,4a,7-hexahydro-1,6-dimethyl-4-(1-methylethyl) | 1528 | 1528 | 0,76 |
| α-Calacorene | 1590 | 1590 | 0,73 |

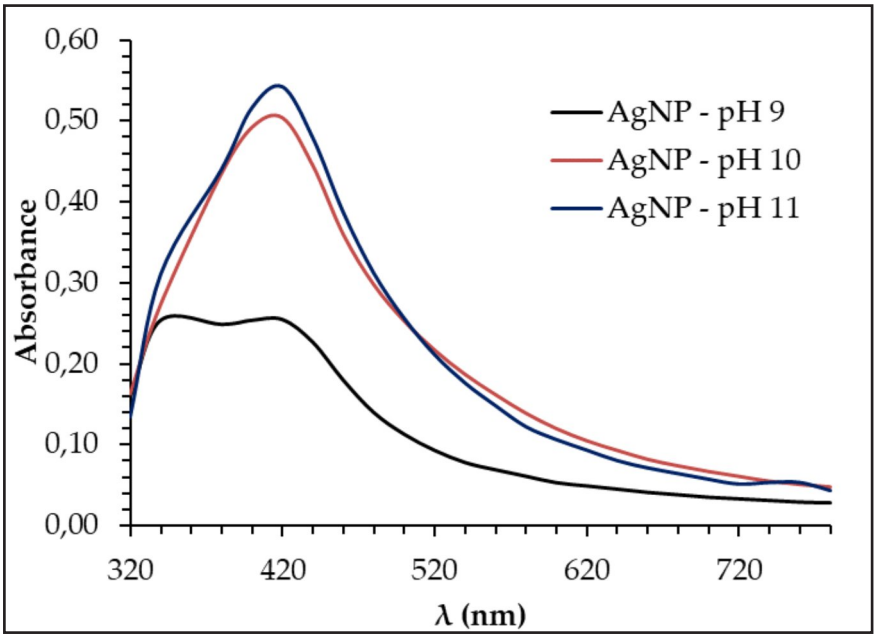
Source: Autorship (2025)
Note: a- Percentages obtained by peak area normalization FID; b-Linear Kovats retention indexes (column DB-5) experimental; c-Theoretical linear Kovats retention indexes

Table 1 shows the chemical constituents identified in the essential oil of *C. verum*. Twenty-one compounds were quantified, with the majority trans-Cinnamaldehyde (82.12%). Similar results are presented by Santurio et al. (2015), which used the barks of C. verum, collected in Brazil, quantifying a total of 4 chemical constituents, with the majority compound trans-cinnamaledehyde with a content of 64.98%. Discordant data were presented by Teles et al. (2022), who collected the barks of the species of *C. verum* in Brazil, quantifying 7 components in the extracted essential oil, being linalool (53.53%), its major component. Discordant results were also shown by Castro et al. (2020), who used the barks of *C. verum*, collected in Brazil, where they quantified a total of 55 components, whose majority compound was α-Cadinol (8.72%).

### 3.2 UV-VIS characterization

Figure 1 presents the UV-Vis characterization of silver nanoparticles obtained from the of *C. verum* essential oil nanoemulsion.

Figure 1 – UV-Vis characterization of silver nanoparticles obtained from the of *C. verum* essential oil nanoemulsion




Source: Authors (2025)

Figure 1 presents the results referring to the UV-Vis characterization referring to silver nanoparticles synthesized through *Cinnamomum verum*. A gradual variation in the color from light yellow to brown was observed during the reaction, due to the excitation of the plasmonic band (Mulfinger et al. 2007), as the pH elevation occurs. The mean diameter obtained ranged from 42.11 to 29.81, according to Table 2.

To observe how efficient the synthesis of silver nanoparticles is, the application in various types of pH using the nanoemulsion of *Cinnamomum verum* essential oil as a reducing agent was studied. All samples were examined by UV-Vis spectroscopy from 320 to 800 nm and particle formation was observed by Surface Plasmonic Resonance (SPR) bands.

The stability of silver nanoparticles were predicted and their corresponding peak of SPR absorption at pH from 9 to 11. It was observed that AgNPs were more stable at higher pH. It is clear from Figure 1 that at lower pH (pH = 9), the nanoparticles presented a wider adsorption peak, which may be due to the larger size of the nanoparticles. By increasing the pH from 9 to 11, the intensity of the peaks was observed (Tahir et al. 2015).

The absorption spectra in UV-Vis have a band (SPR) around 420 nm, admitting the formation of silver nanoparticles Helou (2018). It was observed in the UV-Vis spectrum that the plasmonic resonance band is transferred to longer wavelengths, according to the increase in reaction time, until stabilization around 420 nm.

Table 2 – Average size of the particle diameter of the AgNPs

| *C. verum* | **Average diameter (nm)** | **PDI** | **Zeta potential (mV)** |
|---|---|---|---|
| NPAg-NEO pH 9,0 | 42,11 | 0,477 | -5,36 |
| NPAg-NEO pH 10,0 | 35,14 | 0,355 | -7,66 |
| NPAg-NEO pH 11,0 | 29,81 | 0,304 | -11,14 |

Source: Autorship (2025)
Note: PDI-Polydispersion Index; NPAg-NEO- silver nanoparticles;

The reason *Cinnamomun verum* was used as a reducing agent is due to the presence of reducing compounds capable of synthesizing the nanoparticles. In this species are found chemical compounds, such as the cinnamic aldehyde in the oily phase around 65% and a variety of polyphenols around 35% (Helou, 2018).

The bark of *Cinnamomun verum* is rich in terpenoides, including linalool, eugenol and methyl chavicol (Jayaprakasha et al., 2002; Tung et al., 2008). Terpenoids are believed to play an important role in the biosynthesis of silver nanoparticles by reducing silver ions (Shankar et al., 2003).

### 3.3 Total Phenolic Content

Table 3 presents the results regarding the total phenolic content of the *C. verum* essential oil.

Table 3 – Determination of Total Phenolic Content (TPC) of *C. verum* essential oil

| EO | TPC mg EAT $g^{-1}$ | Equation | $R^2$ |
|---|---|---|---|
| *C. verum* | 126,11 | y=0,0586x+0,06 | 0,9999 |

Source: Autorship (2025)
Note: EO - Essential oil; TPC - total phenolic content.

Table 3 presents the result for the quantification of Total Phenolic Content (CFT). According to Table 1, lower results were presented by Behbahani et al. (2020) when quantifying the CFT of 106.19 mg EAG $g^{-1}$ in the EO of *Cinnamomum verum*, collected in Mashhad, Iran, and extracted by the hydrodistillation method.

Lower results were also observed by Valizadeh et al. (2015) when quantifying the CFT of 53.74 mg EAG $g^{-1}$ in the EO of *Cinnamomum verum*, collected in Tehran, Iran, and extracted by the hydrodistillation method.

According to Aliakbarlu et al. (2013) when quantifying the CFT of 4.89 mg EAG $g^{-1}$, the results obtained were lower for the EO of *Cinnamomum verum*, collected in Urmia, Iran, and extracted by the hydrodistillation method.

### 3.4 Antioxidant activity

Table 4 presents the results regarding the antioxidant activity of silver nanoemulsion and nanoparticle synthesized through the *Cinnamomum verum* essential oil.

Table 4 – Antioxidant activity of *C. verum* essential oil nanoemulsion and nanoparticles formulated from nanoemulsion

| ***C. verum*** | **$IC_{50}$ ppm** | **Equation** | **$R^2$** |
|---|---|---|---|
| NEO | 1,85 | a=49,165; b=36,808 | 0,9127 |
| NPAg-NEO pH 9,0 | 200,98 | a=0,1648; b=16,879 | 0,9979 |
| NPAg-NEO pH 10,0 | 59,46 | a=99,777; b=-127,030 | 0,9999 |
| NPAg-NEO pH 11,0 | 78,80 | a=42,180; b=-30,000 | 0,9999 |

Source: Authorship (2025)
Note: NEO-nanoemulsion; NPAg-NEO-silver nanoparticles

According to Table 4, where the values for the antioxidant activity of the nanoemulsion of *C. verum* essential oil and the formulated bioproduct were quantified, the best result for the nanoemulsion was noted, since it presents the lowest $IC_{50}$. According to Campos et al. (2003), to be considered active, an $IC_{50}$ must be quantified at values lower than 500 mg $L^{-1}$. Thus, it was observed that the nanoemulsion of the essential oil of *C. verum* and silver nanoparticles were active.

Lower results were described Mahomoodally et al. (2019), quantifying the $IC_{50}$ of 3.115 µg $mL^{-1}$ for the OE of *C. verum*. As per Leon-Méndes et al. (2018), quantifying the $IC_{50}$ of 59.00 µg $mL^{-1}$ for the EO of *C. verum* and Mutlu et al. (2023), quantifying the $IC_{50}$ of 5.21 µg $mL^{-1}$ for the EO of *C. verum.*

It was established that this essential oil has antioxidant activity, which is attributed to the presence of phenolic and polyphenolic substances. Cinnamaldehyde (3-phenyl-2-propanal) is the main component of *C. verum* oil from the bark of the species. This compound has several substituters in the aromatic ring, which are useful as starting material in the synthesis of its derivatives. Cinnamaldehyde derivatives have been reported as useful compounds for various applications (Pontiki et al., 2014).

The derivatives of cinnamic acids have been studied because they have antioxidant, anti-inflammatory, antituberculosis and cytotoxic properties. Cinnamate derivatives have been shown to have anti-inflammatory activity (Suryanti et al., 2018).

### 3.5 Anti-inflammatory Activity

Table 5 presents the results regarding the anti-inflammatory activity of nanoemulsion and silver nanoparticles synthesized through the *C. verum* essential oil.

According to Jonville et al. (2011), to be considered active, the $IC_{50}$ must be quantified in values lower than 0.13 mg $mL^{-1}$ and higher than this value is considered moderate and interesting activity. Thus, it was observed that the nanoemulsion of the essential oil of *C. verum* and silver nanoparticles were moderate of interesting activity.

Table 5 – Anti-inflammatory activity of the *C. verum* essential oil nanoemulsion and nanoparticles formulated from nanoemulsion

| ***C. verum*** | **$IC_{50}$ ppm** | **Equation** | **$R^2$** |
|---|---|---|---|
| NEO | 0,2017 | a=201,74; b=-10,704 | 0,9218 |
| NPAg-NEO pH 9,0 | 0,3183 | a=318,28; b=-4,7116 | 0,9954 |
| NPAg-NEO pH 10,0 | 0,6154 | a=0,0707; b=6,4887 | 0,9944 |
| NPAg-NEO pH 11,0 | 0,4348 | a=0,1161; b=-0,4854 | 0,9823 |

Source: Authors (2025)
Note: NEO-nanoemulsion; NPAg-NEO-silver nanoparticles.

Similar results were described by Gogoi et al. (2023), quantifying the $IC_{50}$ of 0.15 µg $mL^{-1}$ for the EO of *C. verum*. Also, analogous results were described by Shaw et al. (2017), quantifying the $IC_{50}$ of 1.00 µg $mL^{-1}$ for the hydroalcoholic extract of *C. verum*. As well as Sivakami et al. (2020), quantifying The $IC_{50}$ of 212.10 µg $mL^{-1}$ for iron nanoparticle synthesized through the hydroalcoholic extract of *C. verum*.

It has been reported that *C. verum* is beneficial for the improvement of many inflammatory diseases, including blood control glucose levels in arthritic pain of diabetes. Despite its widespread use, research on its anti-inflammatory properties was limited (Gunawardena et al., 2015).

## 4 CONCLUSIONS

Finally, silver nanoparticles (AgNPs) were synthesized in an unprecedented way from the essential oil nanoemulsion of *C. verum*. From the CG/MS it was possible quantify 21 chemical constituents, with trans-cinnamaldehyde being the major constituent of the essential oil of *C. verum*. In addition, the IC50 for the antioxidant activity of silver nanoparticles, classified as active, were quantified.

The best result for this test was observed in the NOE and in the nanoparticle with pH 10. silver nanoparticles were also carried out in an unprecedented way, where all tested samples proved to be efficient for antioxidant activity, highlighting the best result for NEO and for the formulation with pH 9. Therefore, it can be inferred that this study brought unprecedented results for silver nanoparticles synthesized from the essential oil nanoemulsion of *C. verum*, where it proved efficient in improving the activities tested in this study, also demonstrating the effect of pH in these formulations.

Finally, silver nanoparticles (AgNPs) were synthesized in an unprecedented way of the essential oil nanoemulsion of *C. verum*. there was a live proportional increase in surface plasmon resonance of silver nanoparticles as Ph increased. From the GC/MS it was possible to quantify twenty-one chemical constituents, the main constituent trans-Cinnamaldehyde of the essential oil of *C. verum*.

In addition, the IC50 for antioxidant activity of silver nanoparticles, classified as active, the best result for this test was observed in the NEO and in the nanoparticle with pH 10. In this study, the quantification of the IC50 of the anti-inflammatory activity of silver nanoparticles was also carried out in a unprecedented way, where all tested samples prove to be efficient for antioxidant activity, highlighting the best result for NEO and for formulations with pH 9.

Therefore, it can be inferred that this study brought in an unprecedented way the results for silver nanoparticles synthesized from the essential oil nanoemulsion of *C. verum*, where it proved efficient in improving the activities tested in this study, also demonstrating the effect of pH in these formulations.

## REFERENCES

Başer, K. H. C., Demirci, B., Dekebo, A., Dagne, E. (2003). Essential oils of some Boswellia spp., myrrh and opopanax. *Flavour and Fragrance Journal*, 18(2), 153-156. doi: https://doi.org/10.1002/ffj.1166

Campos, K. E., Diniz, Y. S., Cataneo, A. C., Faine, L. A., Alves, M. J. Q. F., Novelli, E. L. B. (2003). Hypoglycaemic and antioxidant effects of onion, Allium cepa: dietary onion addition, antioxidant activity and hypoglycaemic effects on diabetic rats. *International journal of food sciences and nutrition*, 54(3), 241-246. doi: https://doi.org/10.1080/09637480120092062

Castro, C. C., da Silva, A. R. C., Franco, C. D. J. P., Siqueira, G. M., Cascaes, M. M., do Nascimento, L. D., Andrade, E. H. A. (2020). Caracterização química do óleo essencial das folhas, galhos e frutos de Cinnamomum verum J. Presl (Lauraceae). *Brazilian Journal of Development*, 6(6), 41320-41333. doi: https://doi.org/10.34117/bjdv6n6-609

Costa, E. V., Dutra, L. M., Salvador, M. J., Ribeiro, L. H. G., Gadelha, F. R., Carvalho, J. E. (2013). Chemical composition of the essential oils of Annona pickelii and Annona salzmannii (Annonaceae), and their antitumour and trypanocidal activities. *Natural Product Research*, 27(11), 997-1001. doi: https://doi.org/10.1080/14786419.2012.686913

Costa, J. S., Barroso, A. S., Mourão, R. H. V., da Silva, J. K. R., Maia, J. G. S., Figueiredo, P. L. B. (2020). Seasonal and antioxidant evaluation of essential oil from Eugenia uniflora L., curzerene-rich, thermally produced in situ. *Biomolecules*, 10(2), 328. doi: https://doi.org/10.3390/biom10020328

Erechim, U. C., Vanin, A. B. (2014). Produção, propriedades biológicas, antioxidantes e toxicidade do bioaromatizante obtido via esterificação enzimática do óleo essencial do cravo-da-índia. http://uricer.edu.br/cursos/arq_trabalhos_usuario/2877.pdf

Evren, A. R. I. N., Ebru, Ö. N. E. M., TABUR, M. A. (2021). Characterization of Myrrh Essential Oil wıth GC-MS and Investigation Antibacterıal Effects on Salmonella spp. *S*üleyman Demirel Üniversitesi Fen Edebiyat Fakültesi Fen Dergisi, 16(1), 319-327. doi: https://doi.org/10.29233/sdufeffd.853138

Ferraz, R. P., Cardoso, G. M., da Silva, T. B., Fontes, J. E. D. N., Prata, A. P. D. N., Carvalho, A. A., Bezerra, D. P. (2013). Antitumour properties of the leaf essential oil of Xylopia frutescens Aubl.(Annonaceae). *Food chemistry*, 141(1), 196-200. doi: https://doi.org/10.1016/j.foodchem.2013.02.114

Figueiredo, P. L. B., Pinto, L. C., da Costa, J. S., da Silva, A. R. C., Mourão, R. H. V., Montenegro, R. C., Maia, J. G. S. (2019). Composition, antioxidant capacity and cytotoxic activity of Eugenia uniflora L. chemotype-oils from the Amazon. *Journal of Ethnopharmacology*, 232, 30-38. doi: https://doi.org/10.1016/j.jep.2018.12.011

Gandlevskiy, N., Viana, A. R., Druzian, G. T., Oliveira, D. K., Schuch, A. P., Barge, A., Cravotto, G., & Flores, E. M. M. (2025). Ultrasound-assisted green synthesis of silver nanoparticles using Ruta graveolens L. extract and antitumor evaluation. *Ultrasonics Sonochemistry*, 117, 107340. https://doi.org/10.1016/j.ultsonch.2025.107340

Govindarajan, M., Rajeswary, M., Senthilmurugan, S., Vijayan, P., Alharbi, N. S., Kadaikunnan, S., Benelli, G. (2018). Curzerene, trans-β-elemenone, and γ-elemene as effective larvicides against Anopheles subpictus, Aedes albopictus, and Culex tritaeniorhynchus: toxicity on non-target aquatic predators. *Environmental Science and Pollution Research*, 25, 10272-10282. doi: https://doi.org/10.1007/s11356-017-8822-y

Guimarães, C. C., Ferreira, T. C., Oliveira, R. C. F., Simioni, P. U., & Ugrinovich, L. A. (2017). Atividade antimicrobiana in vitro do extrato aquoso e do óleo essencial do alecrim (Rosmarinus officinalis L.) e do cravo-da-índia (Caryophyllus aromaticus L.) frente a cepas de Staphylococcus aureus e Escherichia coli. *Revista Brasileira de Biociências*, 15(2). https://seer.ufrgs.br/index.php/rbrasbioci/article/view/114623

Gunawardena, D., Karunaweera, N., Lee, S., van Der Kooy, F., Harman, D. G., Raju, R., Münch, G. (2015). Anti-inflammatory activity of cinnamon (C. zeylanicum and C. cassia) extracts–identification of E-cinnamaldehyde and o-methoxy cinnamaldehyde as the most potent bioactive compounds. *Food & function*, 6(3), 910-919. doi: https://doi.org/10.1039/C4FO00680A

Helou, G. M. R. (2018). Biossíntese de nanopartículas de prata utilizando cinnamomum zeylanicum em matriz de hidrogel para aplicação biomédica. https://repositorio.unifei.edu.br/jspui/handle/123456789/2427

Jakhetia, V., Patel, R., Khatri, P., Pahuja, N., Garg, S., Pandey, A., & Sharma, S. (2010). Cinnamon: a pharmacological review. *Journal of advanced scientific research*, 1(02), 19-23. https://sciensage.info/index.php/JASR/article/view/13

Jayaprakasha, G. K., Rao, L. J., Sakariah, K. K. (2002). Chemical composition of volatile oil from Cinnamomum zeylanicum buds. *Zeitschrift für Naturforschung* C, 57(11-12), 990-993. doi: https://doi.org/10.1515/znc-2002-11-1206

Jonville, M. C., Kodja, H., Strasberg, D., Pichette, A., Ollivier, E., Frederich, M., ... Legault, J. (2011). Antiplasmodial, anti-inflammatory and cytotoxic activities of various plant extracts from the Mascarene Archipelago. *Journal of ethnopharmacology*, 136(3), 525-531. doi: https://doi.org/10.1016/j.jep.2010.06.013

Kumar, B., Yadav, P. R., Goel, H. C., Rizvi, M. (2009). Recent Developments In Cancer Therapy By The Use Of Nanotechnology. *Digest Journal of Nanomaterials & Biostructures (DJNB)*, 4(1). https://www.chalcogen.ro/1-Kumar-Yadav-Goel.pdf

Latha, S., Selvamani, P., Prabha, T. (2021). Pharmacological uses of the plants belonging to the genus Commiphora. *Cardiovascular & Hematological Agents in Medicinal Chemistry*, 19(2), 101-117. doi: https://doi.org/10.2174/1871525718666200702125558

Lima, M. D. P., Zoghbi, M. D. G. B., Andrade, E. H. A., Silva, T. M. D., & Fernandes, C. S. (2005). Constituintes voláteis das folhas e dos galhos de Cinnamomum zeylanicum Blume (Lauraceae). *Acta amazônica*, 35, 363-366.V.N. doi: https://doi.org/10.1590/S0044-59672005000300009

Liu, Y. C., Lin, L. H. (2004). New pathway for the synthesis of ultrafine silver nanoparticles from bulk silver substrates in aqueous solutions by sonoelectrochemical methods. *Electrochemistry communications*, 6(11), 1163-1168. doi: https://doi.org/10.1016/j.elecom.2004.09.010

Madia, V. N., De Angelis, M., De Vita, D., Messore, A., De Leo, A., Ialongo, D., Costi, R. (2021). Investigation of Commiphora myrrha (Nees) Engl. oil and its main components for antiviral activity. *Pharmaceuticals*, 14(3), 243. doi: https://doi.org/10.3390/ph14030243

Marongiu, B., Piras, A., Porcedda, S., Scorciapino, A. (2005). Chemical composition of the essential oil and supercritical CO2 extract of Commiphora myrrha (Nees) Engl. and of Acorus calamus L. *Journal of Agricultural and food chemistry*, 53(20), 7939-7943. doi: https://doi.org/10.1021/jf051100x

Massoud, A. M., El Ebiary, F. H., Abou-Gamra, M. M., Mohamed, G. F., Shaker, S. M. (2004). Evaluation of schistosomicidal activity of myrrh extract: parasitological and histological study. *Journal of the Egyptian Society of Parasitology*, 34(3 Suppl), 1051-1076. https://europepmc.org/article/med/15658062

Mathew, S., Abraham, T. E. (2006). Studies on the antioxidant activities of cinnamon (Cinnamomum verum) bark extracts, through various in vitro models. *Food chemistry*, 94(4), 520-528. doi: https://doi.org/10.1016/j.foodchem.2004.11.043

Mulfinger, L., Solomon, S. D., Bahadory, M., Jeyarajasingam, A. V., Rutkowsky, S. A., Boritz, C. (2007). Synthesis and study of silver nanoparticles. *Journal of chemical education*, 84(2), 322. doi: https://doi.org/10.1021/ed084p322

Nasrollahzadeh, M., Sajadi, S. M., Rostami-Vartooni, A., & Hussin, S. M. (2016). Green synthesis of CuO nanoparticles using aqueous extract of Thymus vulgaris L. leaves and their catalytic performance for N-arylation of indoles and amines. *Journal of colloid and interface science*, 466, 113-119. doi: https://doi.org/10.1016/j.jcis.2015.12.018

Nunes, T. A. L., Santos, M. M., de Oliveira, M. S., de Sousa, J. M. S., Rodrigues, R. R. L., de Araujo Sousa, P. S., da Franca Rodrigues, K. A. (2021). Curzerene antileishmania activity: Effects on Leishmania amazonensis and possible action mechanisms. *International Immunopharmacology*, 100, 108130. doi: https://doi.org/10.1016/j.intimp.2021.108130

Pessoa, J. P. D. M., Oliveira, E. S. F. D., Teixeira, R. A. G., Lemos, C. L. S., Barros, N. F. D. (2016). Controle da dengue: os consensos produzidos por Agentes de Combate às Endemias e Agentes Comunitários de Saúde sobre as ações integradas. *Ciência & Saúde Coletiva*, 21, 2329-2338. doi: https://doi.org/10.1590/1413-81232015218.05462016

Pontiki, E., Hadjipavlou-Litina, D., Litinas, K., Geromichalos, G. (2014). Novel cinnamic acid derivatives as antioxidant and anticancer agents: Design, synthesis and modeling studies. *Molecules*, 19(7), 9655-9674. doi: https://doi.org/10.3390/molecules19079655

Qasim, M., Chae, D. S., Lee, N. Y. (2020). Bioengineering strategies for bone and cartilage tissue regeneration using growth factors and stem cells. *Journal of Biomedical Materials Research* Part A, 108(3), 394-411. doi: https://doi.org/10.1002/jbm.a.36817

Ranasinghe, P., Perera, S., Gunatilake, M., Abeywardene, E., Gunapala, N., Premakumara, S., ... & Katulanda, P. (2012). Effects of Cinnamomum zeylanicum (Ceylon cinnamon) on blood glucose and lipids in a diabetic and healthy rat model. *Pharmacognosy research*, 4(2), 73. doi: https://doi.org/10.4103%2F0974-8490.94719

Rassaei, L., Sillanpää, M., French, R. W., Compton, R. G., & Marken, F. (2008). Arsenite determination in phosphate media at electroaggregated gold nanoparticle deposits. *Electroanalysis: An International Journal Devoted to Fundamental and Practical Aspects of Electroanalysis*, 20(12), 1286-1292. doi: https://doi.org/10.1002/elan.200804226

Rostami-Vartooni, A., Nasrollahzadeh, M., Alizadeh, M. (2016). Green synthesis of seashell supported silver nanoparticles using Bunium persicum seeds extract: application of the particles for catalytic reduction of organic dyes. *Journal of colloid and interface science*, 470, 268-275. doi; https://doi.org/10.1016/j.jcis.2016.02.060

Sandmann, G., Dietz, H., Plieth, W. (2000). Preparation of silver nanoparticles on ITO surfaces by a double-pulse method. *Journal of Electroanalytical Chemistry*, 491(1-2), 78-86. doi: https://doi.org/10.1016/S0022-0728(00)00301-6

Santurio, D. F. (2015). Uso de óleos essenciais de especiarias para controle de coliformes em linguiça toscana (Doctoral dissertation, Universidade Federal de Santa Maria). http://repositorio.ufsm.br/handle/1/3409

Shan, B., Cai Yi-Zhong, Brooks, J. H. (2007). Corke. Antibacterial Prpertis And Major Bioactive Components Of Cinnamon Stick (Cinnamomum burmannii): Activity Against Foodborne Pathogenic Bacteria. *Journal of Agricultural and Food Chemistry*, 55, 5484-5490. doi: https://doi.org/10.1021/jf070424d

Shan, Y. *et al*., Antibacterial Properties and Major Bioactive Components of Cinnamon Stick (Cinnamomum burmannii): Activity against Foodborne Pathogenic Bacteria, *Journal of Agricultural and Food Chemistry*, 55, 5484-5490 (2007). doi: 10.1021/jf070424d. doi: https://doi.org/10.1021/jf070424d

Shankar, S. S., Ahmad, A., Sastry, M. (2003). Geranium leaf assisted biosynthesis of silver nanoparticles. *Biotechnology progress*, 19(6), 1627-1631. doi: https://doi.org/10.1021/bp034070w

Suryanti, V., Wibowo, F. R., Khotijah, S., Andalucki, N. (2018, March). Antioxidant activities of cinnamaldehyde derivatives. *In IOP Conference Series: Materials Science and Engineering* (Vol. 333, No. 1, p. 012077). IOP Publishing. doi: 10.1088/1757-899X/333/1/012077

Tahir, K., Nazir, S., Li, B., Khan, A. U., Khan, Z. U. H., Ahmad, A., Zhao, Y. (2015). Enhanced visible light photocatalytic inactivation of Escherichia coli using silver nanoparticles as photocatalyst. *Journal of Photochemistry and Photobiology B: Biology,* 153, 261-266. doi: https://doi.org/10.1016/j.jphotobiol.2015.09.015

Tan, Y., Wang, Y., Jiang, L., Zhu, D. (2002). Thiosalicylic acid-functionalized silver nanoparticles synthesized in one-phase system. *Journal of colloid and interface science*, 249(2), 336-345. doi: https://doi.org/10.1006/jcis.2001.8166

Teles, Y. C. A., Vieira, A. L. L., Alcantara, K. A., Saraiva, C. R. N. (2022). caracterização química do óleo essencial de Cinnamomum verum (canela). *Revista Interfaces: Saúde, Humanas e Tecnologia*, 10(2), 1332-1335. doi: https://doi.org/10.16891/2317-434X.v10.e2.a2022.pp1332-1335

Tipton, D. A., Lyle, B., Babich, H., Dabbous, M. K. (2003). In vitro cytotoxic and anti-inflammatory effects of myrrh oil on human gingival fibroblasts and epithelial cells. *Toxicology in vitro*, 17(3), 301-310. doi: https://doi.org/10.1016/S0887-2333(03)00018-3

Trajano, E. *et al*. (2010). Inhibitory effect of the essential oil from Cinnamomum zeylanicum Blume leaves on some food-related bacteria, *Ciência e Tecnologia de Alimentos*, 30, 771-775. doi: 10.1590/S0101-20612010000300032

Tung, Y. T., Chua, M. T., Wang, S. Y. Chang, S. T. (2008). Anti-inflammation activities of essential oil and its constituents from indigenous cinnamon (Cinnamomum osmophloeum) twigs. *Bioresource technology*, 99(9), 3908-3913. doi: https://doi.org/10.1016/j.biortech.2007.07.050

Tuutijärvi, T., Lu, J., Sillanpää, M., Chen, G. (2009). As (V) adsorption on maghemite nanoparticles. *Journal of hazardous materials*, 166(2-3), 1415-1420. doi: https://doi.org/10.1016/j.jhazmat.2008.12.069

Tuutijärvi, T., Lu, J., Sillanpää, M., Chen, G. (2010). Adsorption mechanism of arsenate on crystal γ-Fe 2 O 3 nanoparticles. *Journal of environmental engineering*, 136(9), 897-905. doi: https://doi.org/10.1061/(ASCE)EE.1943-7870.0000233

Vangalapati, S. Satya, S. Prakash, S. Avanigadda, (2012). A review on pharmacological activities and clinical effects of cinnamon species, *Research Journal of Pharmaceutical, Biological and Chemical Sciences*, 3, 653-663. https://citeseerx.ist.psu.edu/document?repid=rep1&type=pdf&doi=3e85ede09a3f2f26c36a59df4f804af7131bbb4d

Venturoso, L. R., Bacchi, L. M. A., Gavassoni, W. L., Pontim, B. C. A., & Conus, L. A. (2010). Influência de diferentes metodologias de esterilização sobre a atividade antifúngica de extratos aquosos de plantas medicinais. *Revista Brasileira de Plantas Medicinais*, 12, 499-505. doi: https://doi.org/10.1590/S1516-05722010000400014

Wilkinson, L. J., White, R. J., Chipman, J. K. (2011). Silver and nanoparticles of silver in wound dressings: a review of efficacy and safety. *Journal of wound care*, 20(11), 543-549. doi: https://doi.org/10.12968/jowc.2011.20.11.543

Yu, D. G. (2007). Formation of colloidal silver nanoparticles stabilized by Na+–poly (γ-glutamic acid)–silver nitrate complex via chemical reduction process. *Colloids and Surfaces B: Biointerfaces*, 59(2), 171-178. doi: https://doi.org/10.1016/j.colsurfb.2007.05.007

## Authorship contributions


### 1 – Antonio Felipe Correa Lucas

Bachelor's Degree in Industrial Chemistry (Federal University of Maranhão); Essential Oils Research and Application Laboratory
https://orcid.org/0000-0002-0457-914X - afc.lucas@discente.ufma.br
Contribution: Conceptualization, Data curation, Formal Analysis, Investigation, Methodology, Resources, Software, Visualization, Writing– original draft, Writing– review editing

### 2 – Thamires de Jesus Teles Ribeiro

Bachelor's Degree in Chemistry (Federal University of Maranhão); Essential Oils Research and Application Laboratory
https://orcid.org/0000-0003-1495-9282 - thamiresbelle@gmail.com
Contribution: Conceptualization, Data curation, Formal Analysis, Investigation, Methodology, Resources, Software, Visualization, Writing– original draft, Writing– review editing

### 3 – Américo Pinheiro Neto

Bachelor's Degree in Industrial Chemistry (Federal University of Maranhão); Essential Oils Research and Application Laboratory
https://orcid.org/0009-0005-6095-0336 - americo.pn@discente.ufma.br
Contribution: Conceptualization, Data curation, Formal Analysis, Investigation, Methodology,Resources, Software, Visualization, Writing– original draft, Writing– review editing

### 4- Victor Elias Mouchrek Filho

Full Professor at UFMA (Federal University of Maranhão); Essential Oils Research and Application Laboratory
https://orcid.org/0000-0003-2855-7292 - gustavo.oliveira@discente.ufma.br
Contribution: Funding acquisition, Project administration

### 5- Gustavo Oliveira Everton

PhD in Chemistry (Federal University of Maranhão); Essential Oils Research and Application Laboratory
https://orcid.org/0000-0002-0457-914X - gustavooliveiraeverton@gmail.com
Contribution: Conceptualization, Data, Curation, Formal Analysis, Funding, Investigation, Methodology, Project administration, Resources, Software, Supervision, Validation, Visualization, Writing – original draft, Writing – review editing


## How to quote this article

Lucas, A. F. C., Ribeiro, T. J. T., Pinheiro Neto, A., Mouchrek Filho, V. E. & Everton, G. O.(2025). *Anti-inflammatory and antioxidant potential of silver nanoparticles synthesized using Cinnamomum verum essential oil nanoemulsion*. Ciência e Natura, Santa Maria, 47, e88050. DOI: https://doi.org/10.5902/2179460X88050.