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Chemistry

Green synthesis and biotechnological profile of silver nanoparticles using *Syzygium aromaticum* essential oil nanoemulsion

Síntese verde e perfil biotecnológico de nanopartículas de prata utilizando nanoemulsão de óleo essencial de *Syzygium aromaticum*

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ABSTRACT

This study evaluated the chemical profile, antioxidant, and anti-inflammatory activity, in an unprecedented way, of silver nanoparticles (AgNPs) synthesized from the *Syzygium aromaticum* essential oil nanoemulsion (EON). For essential oil extraction (EO), the hydrodistillation technique was used, and the chemical constituents were identified by GC-MS. Antioxidant activity was evaluated using the method of discoloration of ABTS radicals and anti-inflammatory activity by protein denaturation. The majority constituent of the EO was Eugenol (71,11%). The maximum band of SPR was centered at 420nm indicating the characteristic peak of the AgNPs. The IC_{50} 7,91mg/L for antioxidant activity was obtained for AgNP pH 10. The IC_{50} for anti-inflammatory activity was 0,2163mg/mL. This study brought in an unprecedented way results for AgNPs of *S. aromaticum*, proving to be efficient in improving the activities tested in this study, also demonstrating the effect of pH on these formulations.

Keywords: Antioxidant; Hydrodistillation; Eugenol

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 (NOE) *Syzygium aromaticum*. Para a extração do óleo essencial (OE), utilizou-se a técnica de hidrodestilação e os constituintes químicos foram identificados por CG-EM. A atividade antioxidante foi avaliada pelo método de descoloração dos radicais ABTS e a atividade anti-inflamatória pela desnaturação proteica. O constituinte majoritário do OE foi o eugenol (71,11%). A banda máxima de SPR foi centrada em 420nm, indicando o pico característico das AgNPs. A CI_{50} de 7,91mg/L para atividade antioxidante foi obtida para

AgNP pH 10. A CI_{50} para atividade anti-inflamatória foi de 0,2163mg/mL. Este estudo trouxe de forma inédita resultados para AgNPs de *S. aromaticum*, mostrando-se eficiente na melhoria das atividades testadas neste estudo, demonstrando também o efeito do pH sobre essas formulações.

Palavras-chave: Antioxidante; Hidrodestilação; Eugenol

1 INTRODUCTION

Nanoscience and nanotechnology were introduced as interdisciplinary fields in biology, chemistry, physics, and bioengineering. Nanoparticles, in general, are particles of size from 1 to 100nm and are considered extremely small (Rai et al., 2009; Pandit, 2015).

Metallic nanoparticles have stood out as outstanding products due to their unique combination of advantageous properties such as good conductivity, chemical stability, catalytic, electrical and magnetic properties (Mukherjee et al., 2001; Ajitha et al., 2019). This is due to the antioxidant properties extensively studied for various materials, including natural products, to identify new compounds from natural sources that can act in the synthesis of metallic nanoparticles (Bedlovičová et al., 2020).

The use of plants or plant derivatives for the synthesis of nanoparticles is widely used today, and their compounds often have important biological functionalities that can act synergistically with nanoparticles for various applications in various areas from food to the pharmaceutical and medical industry. The concern with the non-degradation of the environment is even more evident nowadays, which highlights the importance of using sustainable industrial methods capable of proposing alternatives for the reduction of harmful chemical waste (Vilas et al., 2014; Gao et al.; Raja et al., 2017).

Specifically, this research holds that the use of silver ion or metallic silver, as well as silver nanoparticles, can be explored in medicine for treatment of burns, dental materials, coating of stainless steel materials, textile fabrics, water treatment, sunscreens, among others. (Rai et al., 2009).

Various spices, such as *Syzygium aromaticum*, have been used as a medicinal plant for its antioxidant and antimicrobial properties and as a preservative since immortal times.

However, recent research also adds antibacterial, antifungal, antiviral and anticancer spectra to spice plants. *S. aromaticum* is exceptionally good and superlative for other spices because of its strong antioxidant and antimicrobial properties (Mehmood et al., 2020).

Syzygium aromaticum, commonly known as clove, is a plant from the Myrtaceae family that exhibits a wide range of applications owing to its bioactive constituents, notably its essential oil rich in eugenol, along with compounds such as eugenyl acetate, β-caryophyllene, α-humulene, chavicol, and other phenolic constituents (Chaieb et al., 2007).

The essential oil of clove demonstrates notable antimicrobial, anti-inflammatory, analgesic, antioxidant, and anticancer properties, leading to its utilization across various sectors including pharmaceutical, cosmetic, food, and agricultural industries (Hadidi et al. 2020). Consequently, *Syzygium aromaticum* and its essential oil represent a promising source of bioactive compounds with significant potential for diverse applications in health promotion and food preservation (Khatkar et al., 2017).

This species belongs to the family Myrtaceae, well known for its characteristic aroma due to the presence of eugenol and is also rich in non-volatile antioxidants belonging to the group of polyphenols comprising flavonoids, aromatic hydroxy acids, hydrolyzable tannins and their glycosylated derivatives (Yadav et al., 2023).

Thus, 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) *Syzygium aromaticum*.

2 METHODOLOGY

2.1 Collection of plant material

The clove of *Syzygium aromaticum* used in this study were obtained in August 2022, from the federally certified distributor. 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, 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 3h 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 (30m × 0. 25mm). with a DB-5 bonded phase (film thickness, 0.25μm).

Helium was used as a carrier gas with a flow rate of 1.0mL/min. The injector and detector temperatures were 220 and 240°C, respectively. The injection volume of the sample was 0.5μL, 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 to 240°C, followed by an increase of 10°C/min 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 and a scan interval of 0.5 fragments/s. 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±2ºC.

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 48h. 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°C and 25°C for 48h 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 ($AgNO_3$, 1mmol/L) was prepared in distilled water. For synthesis, the pH of the $AgNO_3$ solution was adjusted to 10 with sodium hydroxide solution (NaOH 0.1mol/L). For each condition tested, 10mL 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 1000mg/L, diluted in acetone 1% for the concentrations of 4-167mg/L, added in a volume of 5mL in the reaction system, was prepared, totaling a total volume of 15mL. 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 100-320nm. 3mL of each sample was pipetted in quartz bucket with optical path of 10mm 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 633nm, 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 1.5mL 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). 5mg of samples diluted in 1mL of ethanol were used. To this solution, 7mL of distilled water, 800μL of Folin-Ciocalteu reagent and 2.0mL of 20% sodium carbonate were added. After two hours, the reading was performed in a UV-VIS spectrophotometer at a length of 760nm. The standard curve was expressed in milligrams equivalent to grams (mg EAT/g) 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 100mg/L) in ethanol, the reaction mixture with ABTS radical cation was prepared. In a dark environment, an aliquot of 100μL of each concentration of samples containing 3.0mL of abts radical cation was transferred and after 6 minutes the absorbance of the reaction mixture was read in spectrophotometer at a length of 730nm. 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 (4000μL) consisted of 1000μL of different concentrations of essential oils and e silver nanoparticles (100-500mg/L) diluted in PBS and 3000μL 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 660nm 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 *S. aromaticum* extracted in this study.

Table 1 – Essential oil composition (%) of *S. aromaticum*

RI[b]	RI[c]	Compounds	Content (%)[a]
1388	1389	Eugenol	71,11
1367	1368	Copaene	2,55
1537	1538	Caryophyllene	19,55
1498	1498	Humulene	3,99
1515	1515	Eugenil	2,8

Note: a- Percentages obtained by FID peak area normalization; b- Linear Kovats Retention Rates (column DB-5) experimental; c- Theoretical Linear Kovats Retention Rates
Source: Authorship (2025)

Five compounds were quantified, with the majority being Eugenol with 71.11%. Similar results were observed by Teles et al. (2021), quantified 05 compounds for *S. aromaticum* EO, using the CG/MS technique and reported Eugenol as the majority compound (52.53%), in addition to quantified Caryophyllene (37.25%), humulene (4.11%) and eugenil acetate (4.05%).

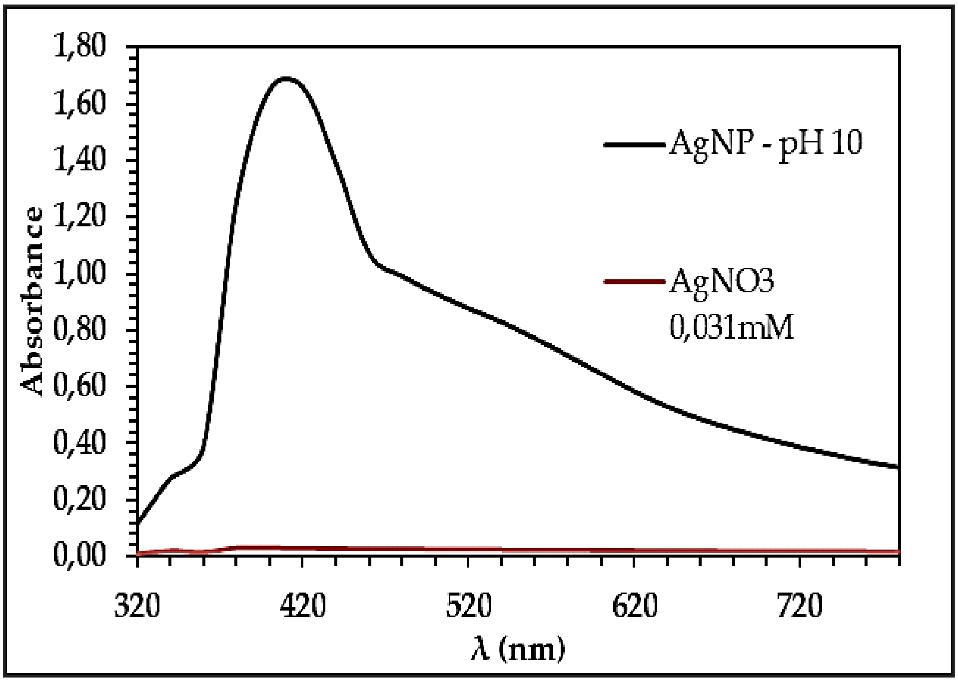
They were also observed by Boughendjioua et al. (2018), quantified 25 compounds for *S. aromaticum* EO, using the CG/MS technique and reported Eugenol as the majority compound (80.00 %), also quantified eugenil acetate (5.01%), β-Caryophyllene (2.27%) and α-farmesene (0.99%).

In addition, it was observed that in the study by Hamad et al. (2018), 12 compounds were quantified for *the EO of S. aromaticum*, using the CG/MS technique and reported Eugenol as the majority compound (75.19 %), β-caryophyllene (18.36%), humulene (2.73%) and caryophyllene oxide (1.13%) were also quantified.

3.2 UV-VIS characterization

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

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



Source: Authors (2025)

To verify the efficiency of AgNP synthesis at different pHs using the of *S. aromaticum* essential oil nanoemulsion as a reducing agent, the samples were analyzed by UV-Vis spectroscopy from 320 to 800nm and particle formation was observed by surface plasmon resonance bands.

The formation of AgNPs occurred due to the reduction of Ag ions in Ag atoms by of the *S. aromaticum* essential oil nanoemulsion added to $AgNO_3$, which was confirmed after the colorless solution was transformed into a yellowish brown. The maximum formation of AgNPs occurred at pH 10 (maximum absorbance at 420nm).

The *S. aromaticum* essential oil has 71.11% of the eugenol compound in its chemical composition, in addition to other compounds in smaller quantities. These compounds have a variety of functional groups with high affinity for noble metals assisting in the stabilization of nanoparticles (Vijayaraghavan et al., 2012).

In addition, the presence of a phenolic ring in the structure of the eugenol allows it to act as a reducing agent through proton donation (H^+). Thus, it is suggested that the reduction of silver nitrate by the *S. aromaticum* essential oil occurs mainly by the action of eugenol, forming the nanoparticles (Maciel et al., 2019).

SPR bands with maximum absorbance at 400-430nm are reported for the synthesis of nanoparticles using an of *S. aromaticum* aqueous extract (Vijayaraghavan et al., 2012), while a maximum absorbance of 435nm is reported for silver nanoparticles of *Cinamommum zeylanicum*, which are like those found in the present study (Sathishkumar et al., 2009).

3.3 Characterization of silver nanoparticles

Table 2 presents the result for dynamic light scattering analysis (DLS) for AgNPs samples synthesized from the *S. aromaticum* essential oil nanoemulsion.

Table 2 – Dynamic light scattering analysis (DLS) for AgNPs samples synthesized from the *S. aromaticum* essential oil nanoemulsion

S. aromaticum	**Medium size (nm)**	**PDI**	**Zeta potential (mV)**
NPAg-NOE pH 10,0	10,2	0,253	-3,99

Note: PDI-Polydispersion Index; NPAg-NOE- silver nanoparticles
Source: Authorship (2025)

The average size obtained by DLS indicates the hydrodynamic radius of the particle. This result reinforces the results observed in the UV-Vis analysis. This study presents in an unprecedented way the synthesis of silver nanoparticles from the nanoemulsion of the species under study. However, it is possible to find in the literature results for diameter of silver nanoparticles from the aqueous extract.

Similar results were obtained in the study of Maciel et al. (2020) by quantifying the average diameter size of 18.6nm for silver nanoparticles synthesized from the *S. aromaticum* aqueous extract by the transmission electron microscopy technique.

Similar results by Venugopal were also observed et al. (2017) when presenting an average diameter size in the range of 5 to 50nm for silver nanoparticles synthesized also from *S. aromaticum* aqueous extract by the transmission electron microscopy technique. In addition, there were also close results in the study of Ajitha et al. (2019) with an average diameter size of 9nm for silver nanoparticles synthesized from the *S. aromaticum* aqueous extract by transmission electron microscopy technique.

The smaller average size quantified in this study is related to the efficiency of essential oils of different plant species in the green synthesis of silver nanoparticles, since these oils are complex substances with considerable bioreductive action (Guimarães et al., 2021). Essential oils are used to reduce metal ions in nanoparticles due to their complex diversity of reducing biomolecules. Some functional groups of oils may interact with different ions, forming bonds that favor the nucleation process of NPs (Maciel et al., 2019).

3.4 Total Phenolic Content

Table 3 presents the results regarding the total phenolic content of the *S. aromaticum* essential oil.

Table 3 – Total phenolic content of *S. aromaticum* essential oil

EO	TPC	Equation	R^2
S. aromaticum	207,62mg EAT/g	y=0,0586x+0,06	0,9998

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

Comparing the results observed in Table 3, lower results were presented in the study of Radünz et al. (2019) by quantifying the TPC of 9.07mg EAG/g of the *S. aromaticum* essential oil collected in Pelotas, Brazil, extracted by the hydrodistillation method.

Lower results were also observed in the study of Bakour et al. (2018) by quantifying the TPC of 16.55mg EAG/g of the *S. aromaticum* essential oil collected in Agadir, Marocco, extracted by the hydrodistillation method.

In addition to these, lower results were also observed in the study of El Ghallab et al. (2020) by quantifying the TPC of 45.57mg EAG/g of the *S. aromaticum* essential oil collected in Casablanca, Marocco, extracted by the hydrodistillation method.

The phenolic compounds quantified in this study consist of hydroxyl substances directly linked to an aromatic hydrocarbon group (Hitz et al., 2018). These can act in the protection against diseases, still presenting high antioxidant, antitumor, anti-inflammatory, antiviral and bactericidal capacity, can provide numerous benefits to the body (Verruck; Prudencio; Silveira, 2019).

These compounds can also act in the body in order to capture excess free radicals that cause tissue degeneration, and can also cause cardiovascular diseases, cancer, among others (Paliyath et al., 2008), mechanisms related to this pharmacological action is the elimination of free radicals (Soobrattee et al., 2009).

3.5 Antioxidant activity

Table 4 presents the results regarding the antioxidant activity of silver nanoemulsion, and nanoparticle synthesized through the *S. aromaticum* essential oil.

Table 4 – Antioxidant activity of *S. aromaticum* essential oil nanoemulsion and nanoparticles formulated from nanoemulsion

S. aromaticum	**IC_{50} mg/L**	**Equation**	**R^2**
NOE	5,10	a= 166,42; b= -67,747	0,9999
NPAg-NOE pH 10	7,91	a=96,947; b= -37,066	0,9998

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

According to Table 4, where the values for the antioxidant activity of the *S. aromaticum* essential oil nanoemulsion and the bioproduct formulated were quantified, the best result for the nanoemulsion was quantified, since it presents the lowest $IC_{50.}$

According to Campos et al. (2003), to be considered active, the IC_{50} should be quantified in values lower than 500mg/L. Therefore, it was observed that the of the *S. aromaticum* essential oil nanoemulsion and silver nanoparticles were active.

Confronting the results obtained in Table 4, there are lower quantitative ones found in the study of Huang et al. (2013) with the IC_{50} of 8,5μg/mL quantified by *S. aromaticum* essential oil test ABTS collected in Guangdong, China. Lower values found in the study of Teles et al. (2021) with the IC_{50} of 78.98μg/mL quantified by the ABTS *S. aromaticum* essential oil test collected in São Luís, Brazil. It can be noted in the study of Adefeghaa et al. (2015) with the IC_{50} of 52,81μg/mL lower result, quantified by the ABTS *S. aromaticum* essential oil test collected in Akure, Nigéria.

The results prove that the *S. aromaticum* essential oil nanoemulsion is capable of acting as a donor of hydrogen atoms or electrons to reduce the ABTS radical. The potent disposal activity of essential oil as well as nanoemulsion and silver nanoparticles can be attributed to the high amount of eugenol (Padmakumari et al., 2011; Gogoi *et al*., 2020).

3.6 Anti-inflammatory Activity

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

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

S. aromaticum	IC_{50} mg/mL	Equation	R^2
NOE	0,2163	a=0,2448; b=-2,9534	0,9990
NPAg-NOE pH 10	0,3583	a=0,1791; b=-14,178	0,3583

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

According to Jonville *et al*. (2011), to be considered active, the IC_{50} should be quantified in values lower than 0,13 mg/mL and higher than this value is considered moderate and interesting activity. Therefore, it was observed that the *S. aromaticum* essential oil nanoemulsion and silver nanoparticles were active.

Comparing the results observed in Table 5, it is found that lower values were presented in the study of Manaswini *et al*. (2019) of 45,39µg/mL by quantifying the anti-inflammatory activity of *S. aromaticum* essential oil collected in Venkatapur, Índia, obtained by the albumin denaturation assay.

It can also be seen in studies of Mahalwal *et al*. (2017) that lower results of 12,50 to 170,80µg/mL were found by quantifying the anti-inflammatory activity of *S. aromaticum* essential oil collected in Cherthala, Índia, obtained by the albumin denaturation assay.

It can also be seen that in the study of Singh *et al*. (2018) lower results were presented, with 158,50 to 170,80µg/mL in the essential oil of *S. aromaticum* collected in Khari Baoli, Delhi, obtained by the albumin denaturation assay.

The potent inhibition activity of protein denaturation of essential oil, as well as nanoemulsion and silver nanoparticles can also be attributed to the high amount of eugenol. The anti-inflammatory effects of eugenol have been attributed to its effect in preventing neutrophil/macrophage chemotaxis and the synthesis of prostaglandins, as well as enzyme expressions of cyclooxygenase II (Nejad *et al*., 2017). In addition, eugenol dummers exhibited a chemopreventive effect by inhibiting the expression of cytokines in macrophages (Leem et al., 2011). Eugenol has been suggested to possess recovery effects on arthritis and therefore can be used in the treatment of arthritis (Grespan et al., 2012).

4 CONCLUSIONS

Finally, silver nanoparticles (AgNPs) were synthesized in an unprecedented way from the *S. aromaticum* essential oil nanoemulsion. From CG/MS it was possible to quantify 5 chemical constituents, eugenol being the major constituent of the S. aromaticum essential oil.

In addition, the IC_{50} were quantified for the antioxidant activity of silver nanoparticles, classified as active, the best result for this assay was observed in the nanoparticle with pH 10. In this study, the quantification of IC_{50} of the anti-inflammatory activity of silver nanoparticles was also carried out in an unprecedented way, where all samples tested demonstrate to be efficient for antioxidant activity, highlighting the best result for the formulation with pH 10.

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

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