ABSTRACT
Cinnamon (Cinnamomum sp) has been used as a spice for millennia, offering nutritional, aromatic, and pharmaceutical properties. The essential oil from cinnamon bark predominantly contains cinnamaldehyde, which exhibits applications as an antioxidant, anti-inflammatory, antimicrobial, and wound-healing agent. These characteristics have drawn the interest of the pharmaceutical industry, seeking to identify alternative uses of this compound for the treatment of oral diseases. In light of this, the present study aims to conduct a literature review, justifying the potential presented by cinnamon essential oil, specifically cinnamaldehyde, for the synthesis of new pharmaceuticals intended for dental use.

Keywords: cinnamaldehyde; antimicrobial; anti-inflammatory.

RESUMO
A canela (Cinnamomum sp) é utilizada como tempero há milênios, oferecendo propriedades nutricionais, aromáticas e farmacêuticas. O óleo essencial da casca de canela contém predominantemente cinamaldeído, que apresenta aplicações como agente antioxidante, antiinflamatório, antimicrobiano e cicatrizante de feridas. Estas características têm despertado o interesse da indústria farmacêutica, buscando...
identificar usos alternativos deste composto para o tratamento de doenças bucais. Diante disso, o presente estudo tem como objetivo realizar uma revisão de literatura, justificando o potencial apresentado pelo óleo essencial de canela, especificamente o cinamaldeído, para a síntese de novos fármacos destinados ao uso odontológico.

**Palavras-chave:** Cinamaldeído; antimicrobiano; anti-inflamatório.

**RESUMEN**

Cinnamomum sp. se ha utilizado como condimento durante milenios, ofreciendo propiedades nutricionales, aromáticas y farmacéuticas. El aceite esencial de la corteza de canela contiene principalmente cinamaldehído, que tiene aplicaciones como agente antioxidante, antiinflamatorio, antimicrobiano y cicatrizante de heridas. Estas características han despertado el interés de la industria farmacéutica, buscando identificar usos alternativos de este compuesto para el tratamiento de enfermedades bucales. Por lo anterior, el presente estudio tiene como objetivo realizar una revisión bibliográfica, justificando el potencial que presenta el aceite esencial de canela, específicamente cinamaldehído, para la síntesis de nuevos fármacos destinados a ser utilizados en odontología.

**Palabras clave:** Cinamaldehído; antimicrobiano; antiinflamatorio.

**1. Introduction**

For centuries, plants have been used by the global population as a source of nutrients and for therapeutic purposes, serving as functional foods. Cinnamon (Cinnamomum sp) is an ancient aromatic spice belonging to the Lauraceae family. According to Silva *et al* (2020), the Lauraceae family consists of 55 species and 12 genera, with an important characteristic being the potential for essential oil production. The scientific name *Cinnamomum* has its origin in Greece, *Kinnámomom*, meaning "sweet wood" (PONCIANO *et al*, 2020).

This plant originates from China and presents itself in the form of a tropical tree cultivated in the southern provinces such as Guangdong, Guangxi, Hainan, and Yunnan, with an estimated 270,000 trees. Its dehydrated stem can be commercialized in the form of dehydrated or crushed stems or as a powder obtained by grinding the stem. Among its health benefits are its antioxidant, anti-inflammatory, antidiabetic, antiallergic, antimicrobial, and wound-healing properties. The strong and sweet-spicy flavor is a distinctive characteristic of cinnamon (BENMOUSSA *et al*, 2023). The active compounds in the essential oil of cinnamon differ depending on the plant part used for extraction, varying between the bark, branches, and leaves (GENG *et al*, 2011). The oil extracted...
from cinnamon bark (OEC) has cinnamaldehyde (CND) as its main constituent, constituting about 75% of the material. This oil is used in the production of essences, seasoning of foods, sauce preparation, in the bakery industry, confectionery, beverage production, and in pharmaceutical preparations (JAYAPRAKASHA; RAO; SAKARIAH, 2014).

Cinnamaldehyde is approved by the Food and Drug Administration (FDA) and exhibits powerful antimicrobial activity against a variety of pathogens, including fungi, Gram-positive and Gram-negative bacteria (FIGUEIREDO et al, 2017). When extracted at room temperature, cinnamaldehyde appears as a yellow, oily liquid, as shown in Figure 1. It can be produced synthetically; however, the most efficient method for its extraction from cinnamon is through steam distillation using the Clevenger apparatus, as depicted in Figure 2.

Cinnamaldehyde, or 3-phenyl-2-propenal according to the International Union of Pure and Applied Chemistry (IUPAC), has a molecular formula of C9H8O, a molecular mass of 132.16 g/mol, a melting point of -7.5 °C, a boiling point of 248 °C, and a density of 1.05 g/cm³ under standard conditions. The structure of cinnamaldehyde is represented in Figure 3, where the functional groups that characterize it are found: aldehyde, carbonyl, and phenyl (YU et al, 2020).

Figure 1: Oily liquid form with vibrant yellow color. 
Source: Elaborated by the author.
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An important physical property of this compound is its high solubility in lipids (PIOVEZAN et al., 2014). It also exhibits low toxicity to human tissues at concentrations of 1,000 to 2,000 micrograms per milliliter (µg/mL) (DIDEHDAR et al., 2022).

Research on natural products in dentistry has increased in recent years due to the antimicrobial, anti-inflammatory, antioxidant, and wound-healing potential that plant products possess. Essential oils are among the greatest sources for the discovery of new promising drugs, showing a real possibility for their applications in the prevention and treatment of oral pathologies.

Moreover, current research on essential oils containing cinnamaldehyde reveals the characteristics of these natural active components, including lower levels of toxicity to the organism, fewer adverse effects compared to synthetic drugs, broad-spectrum antimicrobial activity, low acquisition cost, and the ability to formulate biodegradable medications, thereby reducing environmental contamination (Silva et al., 2023).
Thus, the use of cinnamaldehyde is justified by the potential benefits that this alternative product of natural origin presents compared to traditionally used synthetic drugs.

2. Objective

In light of the above, the aim of this study is to conduct a literature review, seeking to highlight the application of cinnamaldehyde as a pharmaceutical agent in dentistry.

3. Methodology

This study is an integrative literature review (Souza; Silva; Carvalho, 2010), consisting of five consecutive stages.

Stage 1 (literature search): Searches were conducted in the ScienceDirect® and Google Scholar® databases using the keywords: cinnamaldehyde; essential oils; dentistry; antimicrobial; anti-inflammatory.

Stage 2 (inclusion): Selection of studies available in their complete versions, published between the years 2010 to 2023.

Stage 3 (exclusion): Elimination of repeatedly indexed works that did not meet the proposed objective and were unavailable in their complete versions.

Stage 4 (data collection): Collection of information regarding the Author/year of publication, study type, purpose, methodology employed, and respective results.

Stage 5 (writing the review): Organization of the data into a structure comprising an introduction, development (methodology, literature review, and results), discussion, and conclusion. Figure 4 represents the flowchart with the sequential stages employed in the methodology of this study.
4. Literature Review

4.1 Anti-Inflammatory Principle

Cinnamaldehyde (CND) is capable of binding to TNF-α and IL-6 molecules to reduce the levels of pro-inflammatory cytokines, the formation of reactive oxygen species, biomolecular oxidation, and the activity of antioxidant enzymes (MATEEN et al., 2019).

4.2 Antibacterial Principle

The carbonyl groups present in the chemical structure of cinnamaldehyde (CND) can bind to and inhibit the function of the decarboxylase amino acid present in the bacterial structure. It has been demonstrated that destabilizing the electron chain is also a mechanism exerted by the compound to inhibit bacterial growth (MOHAMMADZAMANI et al., 2020).

4.3 Healing Principle:

The healing principle of cinnamaldehyde occurs through the induction of cell proliferation and angiogenesis. This happens by activating the enzyme phosphatidylinositol-3-kinase (PI3K) and MAPKs. Cinnamaldehyde also stimulates the secretion of vascular endothelial growth factor (VEGF), facilitating angiogenesis (YUAN et al., 2018).
Other mechanisms exerted by this substance include reducing levels of interleukin-17 (IL-17) and NO (FERRO et al, 2019).

4.4 Antifungal Principle

It has been proven that cinnamaldehyde (CND) blocks the formation of characteristic structures of these organisms, namely, the mycelia that promote support and nutrition. It also impacts the biosynthesis of ergosterol, a sterol derivative essential for the viability of fungal cells. Ergosterol enables the transport of cell material, promotes the integrity of the plasma membrane, and ensures its proper fluidity. Consequently, the microorganism is destroyed. Inhibiting ergosterol biosynthesis also leads to the disruption of the plasma membrane and damage to the cell wall. Cinnamaldehyde also induces damage to mitochondrial enzymes related to metabolism, such as succinate dehydrogenase (SDHase), enzymes responsible for maintaining mitochondrial function. It also acts on the tricarboxylic acid cycle (NIU et al, 2022).

5. Applications in Dentistry

The use of pharmaceuticals is a significant ally in the cure and treatment of pathologies. A pharmaceutical product is the real presentation of a medication. Presentation forms can be solid, represented by capsules, tablets, drageas, granules, ovules, lozenges, pills, powder, suppositories; liquids, such as solutions, elixirs, emulsions, suspensions; semi-solid forms like creams, gels, lotions, pastes, ointments; and gaseous like sprays (CABRAL; PITA, 2015). Figure 5 schematically illustrates some possible pharmaceutical forms for the synthesis of dental medications.

A pharmaceutical product comprises an active ingredient (medication) and additives (inactive principles). Administration routes can be oral, intravenous, intramuscular, sublingual, buccal, rectal, ocular, otological, nasal, inhalation, cutaneous, as shown in Figure 6. Each administration route has specific advantages, disadvantages, and objectives (GIMENES et al, 2011).
5.1 Prosthesis Disinfectant

Patients using removable complete dentures must perform the hygiene of such devices to avoid the development of a pathology called denture stomatitis.
The microorganisms associated with the onset of this disease are fungi of the species *Candida albicans* (*C. albicans*). The use of sodium hypochlorite (NaOCl) solution has been an effective and economical option. However, its use has disadvantages, including alteration of the color and roughness of the prosthetic material, toxicity to prosthetic support tissues, and unpleasant odor and taste (ALMEIDA et al., 2020). Therefore, due to the deleterious effects of NaOCl, the use of CND as an alternative for the synthesis of denture disinfectants was investigated.

The action of cinnamaldehyde, in vitro, was evaluated for the disinfection of complete dentures containing soft prosthetic reliners with biofilms of *C. albicans* on their surfaces. This action was compared to other commonly used disinfectants: 1% NaOCl, 0.12% chlorhexidine (CHX), and Corega Tabs® effervescent (an antibacterial denture cleaner in the form of effervescent tablets). Its effect on the surface hardness of the resin present in prosthetic devices was also assessed. As a result, CND, at a concentration of 10 milligrams per milliliter (mg/mL), exhibits antifungal activity similar to traditionally used disinfectants. This effect was evident 1 to 10 minutes after immersion. When evaluating surface hardness, prostheses immersed in solutions containing Corega Tabs® and NaOCl showed reduced tensile and shear strengths, with higher values for NaOCl. The use of CND as a disinfectant allows the elimination of the fungus, contributing to the longevity of the denture (BEZERRA et al., 2020).

Given the results, CND has applicability in dentistry as a drug for the disinfection of prosthetic devices, allowing the synthesis of liquid (solutions), semi-solid (gels), and solid (effervescent tablets) pharmaceutical forms from this active ingredient for application on denture surfaces or immersion in solutions. This finding expands the range of dental materials for denture disinfection, especially with low acquisition costs and lower degrees of cellular cytotoxicity.

5.2 Periodontitis Treatment Drug

Periodontitis is a severe pathology that causes damage to insertion structures, tooth mobility, and, in more severe cases, tooth loss due to the destruction of the periodontal ligament and alveolar bone. *Porphyromonas*
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*gingivalis* (*P. gingivalis*) is a Gram-negative bacterium considered the main pathogen involved in this disease, being an aggressive and persistent agent in biofilms located on dental surfaces (BARDAJÍ *et al*, 2016). One of the tools for treating this condition is the use of antibiotics. However, due to the toxic effects of synthetic pharmaceutical agents on the human body and the increased resistance of bacteria to them, OEC was evaluated as a possible active ingredient for the synthesis of new drugs for this purpose.

An in vitro test was conducted to determine the action of the alcoholic extract of cinnamon bark, which mainly contains cinnamaldehyde, to inhibit biofilms formed by *P. gingivalis* and *Aggregatibacter actinomycetemcomitans* (*A. actinomycetemcomitans*). As a result, at a concentration of 7.5% volume per volume (v/v), CND present in the extract shows inhibitory potential on *P. gingivalis* biofilms, and at a concentration of 2.5% v/v, it is effective against *A. actinomycetemcomitans* biofilms. This makes it efficient for the treatment of periodontitis (PANJAITAN *et al*, 2022).

Based on the results, CND (Cinnamaldehyde) demonstrates applicability in dentistry as a drug for the therapy of periodontal disease, enabling the synthesis of solid pharmaceutical forms (tablets, capsules, coated tablets) for systemic action, to be administered orally. Liquid forms (oral rinses) and semi-solid forms (gels and ointments) for local action on oral mucosa and dental surfaces can also be administered orally. This finding expands the range of dental medications for the local and systemic treatment of periodontal disease.

5.3 Drug for Intracanal Medication and Irrigation

The chemical and mechanical preparation for the decontamination of the root canal system involves the use of irrigating solutions to completely eliminate microorganisms causing endodontic infection. CND was studied as a potential agent for canal irrigation and medication. Cinnamaldehyde demonstrated effectiveness against intracanal biofilm formation, bacterial exopolysaccharide formation, proteolytic activities, and hemolytic activities of *Enterococcus faecalis*. In concentrations of 0.47 µg/mL, biofilm formation and proteolytic and hemolytic activities were eliminated, while 28 µg/mL suppressed exopolysaccharide formation.
According to the results, CND has applicability in dentistry for the synthesis of drugs for root canal irrigation during instrumentation and as intracanal medication, particularly in cases of persistent infection. It allows for the production of new liquid (solutions) and semi-solid (gels) pharmaceutical forms for oral administration, providing a low-cost option for dentists with low toxicity, expanding the range of endodontic medications.

5.4 Anti-Cariogenic Drug

Dental caries is a chronic, multifactorial disease, with acidogenic microorganisms like *Streptococcus mutans* (*S. mutans*) and *Streptococcus sobrinus* (*S. sobrinus*) implicated in its etiology. CND was evaluated as a promising option to replace traditional antibacterial agents against *S. mutans* and *S. sobrinus*. The effectiveness of Cinnamaldehyde against *S. mutans* was tested, demonstrating the ability to suppress acid production, mature biofilm, growth of acid-producing agents, and adherence to other bacteria.

CND has applicability in dentistry as an anti-cariogenic drug, enabling the synthesis of liquid (oral rinses) and semi-solid (gels and toothpaste) pharmaceutical forms for local action on oral mucosa and dental surfaces, to be administered orally. It also allows for the synthesis of solid forms (lozenges, chewing gums, and dental floss), providing a low-cost option for acquisition and low toxicity for the treatment and prevention of caries.

5.5 Drug for the Treatment of Candidiasis and Mucositis

Candidiasis, caused mainly by *Candida albicans*, is a reality in dentistry, especially in patients with removable prostheses. CND was investigated as a promising agent for the therapy against oral candidiasis and mucositis lesions infected by *C. albicans*. In vitro studies confirmed the inhibitory action of Cinnamaldehyde against *C. albicans* biofilm formation.

CND has applicability in dentistry as a drug for the treatment of oral candidiasis, systemic candidiasis, and mucositis lesions infected by *C. albicans*. It allows for the synthesis of new liquid (oral rinses) and semi-solid (gels and
ointments) pharmaceutical forms for local use on oral mucosa, to be administered orally. It also enables systemic treatment of candidiasis through the synthesis of solid forms (tablets, capsules, coated tablets), to be administered orally, or liquid forms (intravenous solutions) for parenteral administration.

5.6 Antiinflammatory Drug

Non-steroidal anti-inflammatory drugs (NSAIDs) are commonly prescribed by dentists for controlling inflammation, but long-term use can lead to adverse effects. Research on Cinnamaldehyde as a natural anti-inflammatory drug with fewer toxic side effects has been conducted. CND demonstrated the potential to act as a natural anti-inflammatory medication, reducing the recruitment of neutrophils and macrophages to the inflammatory site when administered through a nanoemulsifying drug delivery system.

Based on the results, CND has applicability in dentistry as an anti-inflammatory drug, enabling the synthesis of solid pharmaceutical forms (tablets, capsules, coated tablets) for systemic action, to be administered orally, and the synthesis of semi-solid forms (ointments and gels) for local action, to be administered through the skin (cutaneous) or orally (oral mucosa). This finding broadens the range of dental medications for the therapeutic management of inflammation.

5.7 Drug for Halitosis Treatment

Halitosis negatively impacts an individual's self-image, causing psychological consequences such as depression, low self-esteem, and social isolation. Cinnamaldehyde was studied for its antibacterial activity against microorganisms involved in the formation of volatile sulfur compounds responsible for bad breath. CND demonstrated antibacterial effects against *Fusobacterium nucleatum, Porphyromonas gingivalis, Prevotella intermedia*, and *Parvimonas micra*, with bactericidal concentrations ranging from 50 µg/mL to 400 µg/mL.

CND has applicability in dentistry as a drug for the therapy of chronic halitosis, enabling the synthesis of solid forms (lozenges and chewing gums),
semi-solid forms (gels), liquid forms (oral rinses), and gaseous forms (spray), for local action on oral mucosa and dental surfaces, to be administered orally. This expands the range of dental drugs for halitosis treatment.

5.8 Healing Drug

Wound healing is crucial, especially postoperatively in maxillofacial surgeries involving dentoalveolar trauma for extractions and implant installation. Patients with systemic comorbidities, like type 2 diabetes, face challenges in wound healing. Cinnamaldehyde was evaluated as a wound healing and antimicrobial compound in polymer-based dressings. The microporous dressings with 3.5% cinnamaldehyde demonstrated good antimicrobial performance.

CND has applicability in dentistry as a wound healing drug, enabling the synthesis of semi-solid forms (gels and ointments) for local application on oral mucosa, to be administered orally, and for topical use on post-surgical wounds, to be administered through the skin. Cinnamaldehyde can also be added to commercially available wound dressings (foam, films, hydrogels, and fibers), improving their properties. This finding broadens the range of dental drugs for wound healing, particularly in oral surgery.

6. Discussion

The active components of cinnamon, particularly cinnamaldehyde, offer various benefits for treating oral cavity diseases (CHEW et al, 2021). Cinnamaldehyde, a pharmacologically active compound found in cinnamon bark, possesses antibacterial, antifungal, anti-inflammatory, and wound-healing properties (USAI; SOTTO, 2023). Recognized as a safe substance by the FDA and exhibiting low tissue toxicity, cinnamaldehyde holds promise for application in dentistry (FIGUEIREDO et al, 2017; DIDEHDAR et al, 2022).

Cinnamaldehyde’s capability to eliminate bacteria involves degrading cell walls, destabilizing energy processes, and altering cellular structures (ALMEIDA; ALMEIDA; GHERARDI, 2020; MOHAMMADZAMANI et al, 2020; NAZZARO et al, 2013). In fungal cells, it inhibits energy synthesis, cell division, and cellular structure formation (SHREAZ et al, 2016; ALVES et al, 2022; NIU et al, 2022).
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Additionally, cinnamaldehyde demonstrates immunomodulatory properties by reducing inflammation through its impact on macrophages and monocytes, inhibiting inflammatory cell aggregation and migration, and decreasing pro-inflammatory cytokine levels (KIM; NA; LEE, 2018; KIM et al, 2010; MATEEN et al, 2019).

Cinnamaldehyde's wound-healing mechanism involves stimulating new blood vessel formation, reducing cytokine levels, and promoting collagen type I synthesis (YUAN et al, 2018; FERRO et al, 2019; TAKASAO et al, 2012).

Different forms of cinnamaldehyde, including essential oil, aqueous extract, ethanolic extract, and nanoemulsion, have shown satisfactory results in various studies. Essential oil usage was most prevalent, followed by aqueous extract, ethanolic extract, and nanoemulsion. All these forms exhibited promising effects, showcasing the versatility of cinnamaldehyde across various applications (Figure 7).

Figure 7: Percentage of studies utilizing different forms of the active compound organized in the image graph.

These principles pave the way for incorporating cinnamaldehyde into diverse pharmaceutical forms, enabling the synthesis of new natural active ingredient-based dental drugs. These medications can target prosthetic device disinfection, periodontal disease treatment, endodontic infection treatment, and...
prevention and treatment of dental caries, halitosis control, inflammation management, candidiasis and mucositis treatment, and wound healing medications. This variety of applications underscores the potential relevance of cinnamaldehyde in developing innovative dental therapies.

7. Conclusion

Plants have been utilized by humans for various purposes, but many lack proven efficacy. Therefore, research aiming to identify natural products with medicinal properties serves as an alternative for disease treatment. Essential oils are sources of active compounds with potential antimicrobial activity, lower toxicity levels, and the ability to biodegrade in the environment. Cinnamaldehyde proves to be promising for use in dentistry. Due to its antibacterial, antifungal, anti-inflammatory, and wound-healing properties, this active ingredient is considered, in various studies, for the therapy of oral pathologies. Thus, it is concluded that this substance enables the synthesis of natural-origin dental drugs, possibly replacing traditionally used synthetic medications due to their considerable side effects. However, further studies are still needed to better elucidate its physicochemical characteristics and its spectrum of action. For the development of improved active release systems and a better understanding of its synergistic action when combined with other agents, ensuring its broad, safe, and effective use in dentistry.

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