A Review of the Pharmacognostic Account of Cinnamon and its use in Daily Life

[1] Prachal S. Virutkar, [2]Kanchan Raut, [3]Niraj Dhande, [4]Ritvika Chaudhari
B Pharm Nagpur College of Pharmacy Wanadongari Hingna, Nagpur

Abstract:- Cinnamon, scientifically known as Cinnamomum zeylanicum and Cinnamon cassia, belongs to the Lauraceae family and has been recognized as a valuable tree in tropical medicine. It has been utilized for centuries as a popular flavoring agent and has also found a place in traditional Eastern medicine. Cinnamon extracts, particularly vital oils, contain biologically active compounds such as cinnamon aldehyde, cinnamic alcohol, cinnamic acid, and cinnamate. This spice holds immense significance globally, being a staple in everyday cuisine. Cinnamon has been found to possess a wide range of beneficial properties, including antioxidant, anti-inflammatory, antidiabetic, antimicrobial, anticancer, lipid-lowering, and cardiovascular-disease-lowering effects. Moreover, recent research suggests that cinnamon may also exhibit potential against neurological disorders like Parkinson's and Alzheimer's diseases. This review aims to provide a comprehensive overview of the cinnamon plant, covering aspects such as its morphology, macroscopic and microscopic characteristics, chemical constituents, cultivation, collection, and processing methods. Furthermore, the review explores the pharmacognostic medicinal uses of cinnamon, highlighting its historical and contemporary applications in traditional medicine. It also touches upon toxicological data and potential adverse drug reactions associated with cinnamon consumption. Additionally, the review delves into the current and future industrial applications of cinnamon, showcasing its versatility beyond the realm of traditional medicine. In conclusion, cinnamon is a valuable spice with a rich history and a diverse range of uses. Its pharmacological potential and therapeutic applications make it an intriguing subject of study. By summarizing the available information on cinnamon, this review provides insights into its multifaceted nature and its potential impact on various aspects of daily life.

Keywords:- *Cinnamon, Diabetes, Parkinson's, Blood*

I. INTRODUCTION

Cinnamon, a spice with a long history, is native to Sri Lanka and is the world's major producer and exporter of cinnamon bark and leaf oil, spanning over 24,000 hectares of cultivation. Its taxonomical name, Cinnamomum zeylanicum, reflects its original homeland's former name, Ceylon. The genus Cinnamomum, which belongs to the Lauraceae family, comprises around 250 aromatic and flavoring species found in Southeast Asia, China, and Australia. The most common type of cinnamon found in commerce is derived from the Cinnamomum verum tree, also known as Cinnamomum zeylanicum Blume. It is recognizable by its pale tan color and mildly sweet flavor. However, there is another spice called cassia, similar to cinnamon but of inferior quality, native to Myanmar (Burma). Various species of cassia, such as Chinese cassia, Indonesian cassia, and Indian cassia, are sourced from different regions.

While Sri Lanka historically accounted for 90% of the world's cinnamon production, China, India, and Vietnam are also significant producers. In contrast, Indonesia leads in cassia cinnamon production, responsible for 40% of the global supply. Cinnamon from Sri Lanka boasts distinct advantages due to its exceptional organoleptic properties, and the island hosts a wide range of cultivars, each characterized by unique sensory attributes such as 'sweet,' 'honey,' 'camphoraceous,' 'mucilaginous,' 'wild,' and 'bloom. 'Cinnamon cultivation is also prominent in India, particularly in Kerala, coastal areas of Karnataka, and various parts of Tamil Nadu, as well as in islands like the Andaman Islands, Nicobar Islands, Lakshadweep, and the Maldives. Apart from its culinary use, cinnamon bark and leaf oil hold significance in the international market. Sri Lanka is a major supplier of cinnamon bark oil, with France being its largest importer, followed by the USA. Additionally, Sri Lanka and Seychelles are known for distilling leaf oil, which enjoys a considerable market share in the USA and Western Europe. China stands as the primary global producer of cassia oil, with smaller quantities also originating from Indonesia, Vietnam, India, and Nepal, although not as extensively traded as Chinese cassia oil. As the spice trade continues to thrive, major importers of cinnamon include Mexico, West Germany, the USA, the UK, Saudi Arabia, Taiwan, Singapore, Hong Kong, and France, while the demand for cinnamon cultivated in Sri Lanka remains high due to its excellent quality and diverse cultivars.

II. CINNAMON

Cinnamon holds great importance as an age-old spice and fragrant crop, boasting a range of uses in flavoring, perfumery, and medicinal practices. Its name originates from a Greek term signifying "sweet wood." This versatile spice has been embraced and incorporated into various culinary traditions across numerous societies throughout the course of history [1].

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- **Biological source:** Dried inner bark of the shoots of coppiced threes of Cinnamomum zeylanicum (Cinnamomum verum)
- **Family:** Lauraceae.
- **Common Names**: French: Cannellier, canella de Ceylan
- Hindi: Dalchini, ilayangam
- Marathi: Dalchini.

Cinnamon is an ancient and valuable spice with a diverse range of uses in flavoring, perfumery, and medicine. It is derived from a plant that contains different active compounds, leading to distinct properties in various parts of the plant. The leaves, bark, and root bark produce volatile oils with differing primary compounds: cinnamon aldehyde in the bark, eugenol in the leaf oil, and camphor in the root bark oil. Beyond its delicious taste, cinnamon has attracted attention in the pharmaceutical field due to its health-promoting properties. The secondary metabolites in cinnamon, such as phenolic acids, coumarin, proanthocyanidin, and volatile essential oils, are considered safe and beneficial for health. These compounds act as natural antioxidants in many food recipes. The objective of the project was to comprehensively explore cinnamon's morphology, active compounds, and biological properties, with a focus on their potential impact on human health. The study also investigated how cinnamon's compounds could be incorporated into diets for individuals with various diseases or metabolic disorders. By summarizing these aspects, the project aimed to contribute to the existing knowledge about cinnamon and its potential applications in healthcare and nutrition. This review extensively covers the chemical and biological properties of cinnamon, belonging to the Lauraceae family, and its potential use as a spice and medicinal agent. It highlights the variations in cinnamon oils and their applications in the food industry. The review consolidates the latest research studies on cinnamon to provide an up-to-date and comprehensive understanding of its potential as a spice. In the current world, finding sustainable sources of natural remedies is crucial, and cinnamon bark stands out as an excellent example. However, further research is needed to confirm the specific health benefits of cinnamon for various diseases.

- *Representative photographs of Cinnamon*

Dried bark strips, bark powder, and flowers of the small tree Cinnamomum verum

Cinnamomum verum, from Koehler's Medicinal Plants (1887)

Close-up view of raw cinnamon bark

Fig 1 Representative Photographs of Cinnamon (adopted from Google search and Wikipedia).

III. HISTORY

Cinnamon, known for its delightful sweetness, holds a special place among spices, while cassia serves as a coarser alternative. The botanical name of cinnamon, Cinnamomum, is derived from the Hebrew and Arabic term "common," signifying a fragrant spice plant. Both cinnamon and cassia were highly prized spices in ancient Greece and Rome. The term "cinnamon" itself comes from the Greek word "Kinnamon." Cinnamon has been used in religious ceremonies since ancient times, with references found even before the era of Moses in various religious texts such as the

Bible (Exodus, Proverbs, and Song of Songs) and ancient Chinese writings dating back 4,000 years [7].In Exodus 30:22–26, there is a passage where the Lord instructs Moses to gather various principal spices, including pure myrrh, sweet cinnamon, sweet calamus, and cassia, to create a holy anointing oil. This biblical reference highlights the historical significance of cinnamon as one of the esteemed spices used in religious rituals. Cinnamon was so highly valued that it was considered more valuable than gold. An anecdote recounts that Roman Emperor Nero burned an entire year's supply of cinnamon during his wife's funeral, showcasing its extravagant worth. Additionally, ancient Egyptians over 3,600 years ago utilized cinnamon in embalming practices. Throughout history, various historical figures have documented and mentioned cinnamon. In 1275 AD, the Arab writer Kasawini made references to cinnamon, followed by John of Montecorvino, a Minorite friar, who wrote about it around 1293 AD. Renowned Arab traveler Ibn Battuta also mentioned cinnamon in his books around 1340 AD. These accounts highlight the widespread knowledge and usage of cinnamon during that period. In the eighteenth century, a Dutchman named Francois Valentijn provided detailed descriptions of cinnamon bark harvesting in his writings, shedding light on the practices and techniques involved in obtaining cinnamon during that era. One notable historical figure associated with cinnamon is Vasco da Gama, a Portuguese explorer. In the fifteenth century, da Gama successfully navigated a sea route from Europe to India and brought back various spices, including cinnamon, to Portugal from the city of CalicutIn China, cinnamon was used medicinally as early as 2500 BC. The Portuguese, driven by their desire for cinnamon, invaded Sri Lanka shortly after reaching India in 1536 [8].

IV. METHOD AND USED

- *Harvest*

The process of harvesting cinnamon bark usually begins after the second or third year of planting, and subsequent harvests are done every 12 to 18 months. The selected branches are carefully processed by removing the outer bark through scraping, followed by even beating with a hammer to loosen the valuable inner bark. The outer bark of the cinnamon tree is thick and brownish, while the inner bark is the prized part used for cinnamon. During the wet season, the trees are cut, with a focus on the central portions of the shoots. The highest quality cinnamon bark is obtained from shoots that are uniformly brown and have a length of 1.0-1.25 meters and a diameter of 1.25 centimeters. The best time to cut the stems is when the red flush of the young leaves turns green, indicating a smooth flow of sap between the bark and wood. The selected shoots for peeling are separated from the stems, and their terminal ends are removed. Cinnamon harvesting primarily occurs in two main seasons, typically in May and November, although limited-scale harvesting takes place throughout the year. Skilled peelers decide the optimal time for cutting shoots based on the circulation of sap between the root and corky layer. They can assess this by performing a test cut on the stem [9-12]. This process of harvesting and production plays a crucial role in obtaining the highly valued cinnamon spice that is used in various medicinal applications.

- *Processing:*

The processing of cinnamon bark is a critical step that should be carried out immediately after harvesting while the bark is still moist. According to Azam Ali (2007), bark processing constitutes about 60% of the total production cost of cinnamon. Skilled peelers typically perform the labor-intensive task of hand-peeling the bark from the stems, and the quality of the cinnamon greatly depends on their expertise in this process. Drying is a significant aspect of cinnamon processing and significantly impacts the final product's quality. The extracted cinnamon bark, known as quills, is placed on coir rope racks and dried in the shade to prevent warping. After about 4 or 5 days of drying, the quills are rolled on a board to tighten the filling, and then they undergo further drying in subdued sunlight. In regions with high humidity or during the rainy season, mechanical dryers like electrical, gas-fired, or biomass-fueled dryers may be necessary to complete the drying process [13, 14].

The initial harvest typically yields quills weighing between 60 to 125 kg per hectare, while older plants aged 10 to 12 years can produce approximately 225 to 300 kg of quills per hectare. Larger intact quills or bigger pieces may fetch a higher price compared to smaller broken pieces. After removing the bark from the stems, it takes about 4 to 6 hours for the bark to completely dry if kept in a well-ventilated and relatively dry environment. Otherwise, there is a risk of pests infesting the bark, which would then require fumigation. However, fumigated bark is not considered of premium quality [14]. Proper and meticulous processing, including skilled peeling and careful drying, is essential to ensure the high quality and desirability of cinnamon, which remains a popular and valuable spice used in various culinary and medicinal applications.

- *Production of Quills*

The commercial products derived from cinnamon include quills, quillings, featherings, chips, cinnamon bark oil, and cinnamon leaf oil. The production of quills involves several stages:

- *Peeling*

The process of extracting cinnamon quills begins with peeling the harvested cinnamon shoot. Skilled workers use a special knife to carefully scrape off the rough outer bark. To facilitate easier peeling, the surface is further polished with a brass rod. A longitudinal slit is then made from one end of the shoot to the other, and the bark is gently peeled off. To improve efficiency and minimize the risk of damage to the cinnamon stems, the Agricultural Engineering University of Ruhuna in Sri Lanka has developed a small machine specifically designed to take out the bark from cinnamon stems [15, 16]. This machine streamlines the peeling process, making it more efficient and reducing the chances of harming the cinnamon stems. Using this specialized machine ensures that the extraction of cinnamon quills is done with precision and care, preserving the quality and value of this prized spice used in various culinary and medicinal applications.

- *Rolling*

After the peeling process, the cinnamon barks are packed together and stacked on top of each other, ensuring a firm press. The bark slips are then trimmed to a length of around 20 cm and piled up in small enclosures created with sticks. To preserve moisture for the following day's operation and to promote a slight fermentation process, the piled bark slips are covered with dry leaves or mats. This step helps retain moisture, which is crucial for the subsequent operation known as piping.

- *Piping*

After the initial processing of cinnamon, the rolled cinnamon slips are taken to the piping yard for further operations. In this stage, the outer skin of the slips is carefully scraped off using a small curved knife. The scraped slips are then sorted into different grades based on their thickness. Trimmed slips have their ends cut and pressed over pipes. These slips are tightly rolled around the pipes and left to dry. During the drying process, smaller quills can be inserted into larger ones, creating compound quills called pipes. To ensure the quills don't warp, they are arranged in parallel lines in shaded areas for drying. Direct exposure to sunlight can lead to deformation or warping of the quills.Once dried, the resulting quills consist of a mixture of coarse and fine types and have a yellowish-brown color. In some cases, a bleaching process using sulfur treatment for approximately 8 hours may be carried out on the quills [17]. This process helps achieve the desired color and appearance.

- *Production of Ground Cinnamon*

Grinding cinnamon to a powder can be a value-added method, but it is important to note that the heat generated during grinding can be detrimental to the volatile oil content of cinnamon. Cryogenic grinding, on the other hand, helps to preserve more of the volatile compounds and is considered more suitable for cinnamon. However, it is crucial to recognize that grinding cinnamon reduces its shelf life. The flavors and aroma compounds in ground cinnamon are not stable and can quickly dissipate, making it more susceptible to spoilage. There are additional factors to consider regarding ground spices. It becomes challenging for consumers to assess the quality of ground spices, and there is also an increased risk of contamination when unscrupulous processors add other materials to the ground spice.

- *Production of Oils and Oleoresins*

For the production of cinnamon bark oil, hydrodistillation or steam distillation methods are commonly employed. The process involves using cinnamon chips, featherings, or quillings as the raw material for extraction. Cinnamon bark can obtain two types of oils: a superior type obtained from the inner bark and a lower quality oil obtained from broken quills, chips, and bark pieces. It is important to ensure that the barks to be distilled for oil extraction are not placed in wet bundles or exposed to dampness, as this can lead to mold growth or fermentation, which can negatively impact the oil's profile. Additionally, the leaves of cinnamon can also be used as a raw material for extracting leaf oil. It is reported that approximately 1 tonne of leaves can be obtained from 1 hectare of cinnamon plants. Steam distillation of the leaves yields approximately 2.5-3 kg of oil, which is rich in eugenol. Cinnamon and cassia oils are typically subjected to rectification to achieve a more standardized composition. Additionally, cinnamon oleoresin is produced from Indonesian cassia specifically for flavoring purposes. The process of obtaining oleoresin involves extracting the barks using organic solvents. When ethanol is used as the solvent, the yield ranges from 10 to 12%. On the other hand, benzene extraction results in a yield of 2.5 to 4.3%. In recent years, the solvent 1,1,2-trichloro-1,2,2-trifluoroethane has gained popularity for oleoresin extraction [19].

- *Packaging*

When packaging cinnamon, especially in its ground form, polypropylene is recommended over polythene. Polythene cannot be used for packaging cinnamon as the flavor components of cinnamon can diffuse through it. Cinnamon quills are cut into pieces up to 10 cm in length, and they are typically packed in moisture-proof polypropylene bags for sale. It is important to seal the bags properly to prevent moisture from entering. According to Azam Ali [20], the packaging label should contain all relevant product and legal information, including the name of the product, brand name (if applicable), manufacturer details (name and address), date of manufacture, expiry date, weight of the contents, and any added ingredients if relevant. The label should also comply with any specific requirements of the country of origin and import, such as including a barcode, producer code, packer code, and any other necessary information for product traceability. For wholesale export, cinnamon quills are typically packed in compact cylindrical bales weighing 50 kg and wrapped in jute cloth. Additionally, a new cinnamon-based active paper package has been developed, incorporating cinnamon essential oil at a concentration of 6% (w/w) in solid wax paraffin. The essential oil in this active coating formulation effectively inhibits the growth of Rhizopus stolonifer, a common mold [20].

- *Storage*

According to Azam Ali [20], proper storage of dried cinnamon quills is essential to maintain their quality. It is advised to store them in moisture-proof containers and keep them away from direct sunlight. Regular inspections should be conducted to detect any signs of spoilage or moisture absorption. In case the cinnamon quills have absorbed moisture, they need to be re-dried until their moisture content reaches 10%. This helps prevent spoilage and maintain their desirable characteristics. The storage room should be maintained in a clean, dry, and cool condition to ensure the longevity of the cinnamon quills. Additionally, it is crucial to keep the storage room free from pests. To prevent pests and insects from entering the room, one recommendation is to install mosquito netting on the windows. When packaging ground cinnamon powder, it is advisable to use moisture-proof packaging materials such as polypropylene bags. This helps preserve the flavor and quality of the powder over time.

V. DESCRIPTION OF CINNAMON (MORPHOLOGY)

The cinnamon tree is a tropical evergreen species that can reach a height of up to 7 meters in its natural state. However, when cultivated, it is often grown as a bush, resulting in a height of less than 3 meters. This is achieved by continuously cutting back the stems to promote the growth of new shoots, which are used for extracting bark/quills. The cinnamon tree features thick and rough bark, as well as sturdy branches. Cinnamon bark is widely utilized as a spice and is known for its pleasing fragrance and warm, sweet, aromatic taste, both in its natural state and when cooked. The leaves of the cinnamon tree are ovate-oblong in shape, measuring 7 to 18 centimeters in length. They possess a slightly hot and bitter taste and emit a mouth-watering fragrance when cooked or fried. The flowers of the cinnamon tree are arranged in panicles and have a greenish color, accompanied by a distinct aroma. The fruit of the cinnamon tree is a purple berry, about 1 centimeter long, which contains a single seed. The cinnamon tree thrives best in a hot and wet tropical climate at low altitudes. It typically reaches a harvest-ready stage after three years of growth. It is important to note that the soil should not be waterlogged, as this can result in the production of bitter-tasting bark. The bush-like cinnamon plant usually develops eight to ten side branches, which are harvested after about three years to obtain high-quality cinnamon bark. Cinnamon spice is primarily derived from drying the central part of the bark, which is then marketed as quills or powder. Dried cinnamon leaves are sometimes used in spice mixtures as well. The essential oil extracted from cinnamon bark serves as a concentrated source of cinnamon flavor, particularly in the canned food and confectionery industries. The distinctive smell and aroma of cinnamon stem from the volatile oils present in the bark or leaves [21]. There is often confusion between cinnamon and cassia. While cinnamon and cassia are not identical, they are closely related, and their barks share many similarities. It may come as a surprise to many that what is commonly sold as cinnamon in American stores is largely cassia.

A. *Chemical Constituents*

Cinnamon contains various resinous compounds that contribute to its aroma, flavor, and physiological properties. Some of the key compounds found in cinnamon include cinnamaldehyde, cinnamate, cinnamic acid, and several essential oils. Cinnamaldehyde is particularly responsible for the spicy taste and fragrance of cinnamon and is known to undergo oxidation upon exposure to oxygen, leading to the development of its characteristic flavors. As cinnamon ages, it tends to darken in color, which can enhance the presence of resinous compounds [19].

Table 2 Chemical Constituents of Different Parts of Cinnamon.

Part of the plant	Compound
Leaves	Cinnamaldehyde: 1.00 to 5.00%
	Eugenol: 70.00 to 95.00%
Bark	Cinnamaldehyde: 65.00 to 80.00%
	Eugenol: 5.00 to 10.00%
Root bark	Camphor: 60.00%
Fruit	*trans*-Cinnamyl acetate (42.00 to 54.00%) and caryophyllene (9.00 to 14.00%)
***C. zeylanicum* buds**	Terpene hydrocarbons: 78.00%
	alpha-Bergamotene: 27.38%
	alpha-Copaene: 23.05%
	Oxygenated terpenoids: 9.00%
***C. zeylanicum* flowers**	(E)-Cinnamyl acetate: 41.98%
	trans-*alpha*-Bergamotene: 7.97%
	Caryophyllene oxide: 7.20%

Table 3 Physicochemical Properties of Cinnamon.

Parameter	Leaf oil	Bark oil
Specific gravity (20°C)	1.030–1.050	1.010–1.030
Optical rotation (°) (20°C)	1°96′–0°40′	Slightly laevorotatory
Refractive index (20°C)	1.529–1.537	1.573–1.591
Aldehyde content	4%	65–76%
Eugenol content	77.3–90.5%	4–10%
Solubility characteristics	Soluble in 1.5 volumes of70% alcohol	Soluble in 2.0–3.0 volumes of70% alcohol

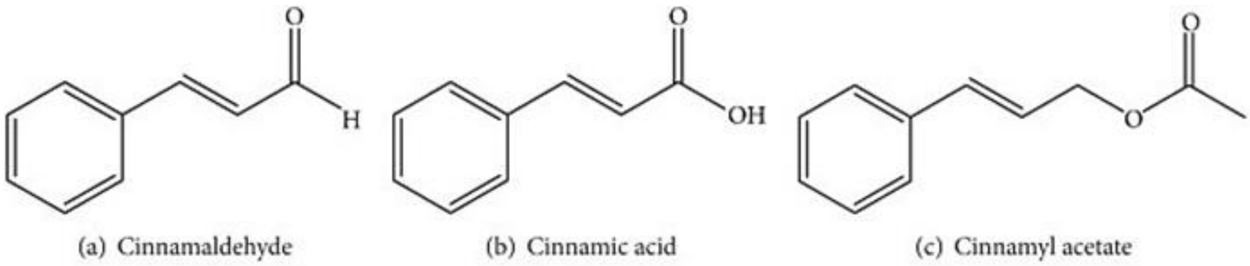

Fig 2 Cinnamyl Group-Containing Compounds.

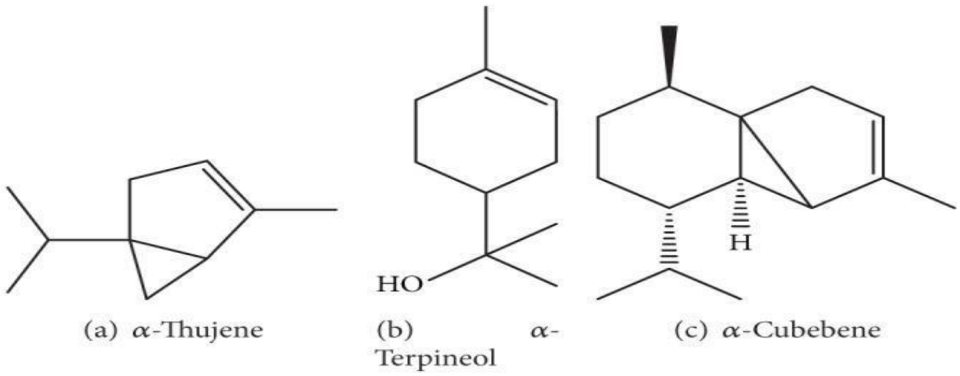

Fig 3 Endocyclic Double Bond-Containing Compounds.

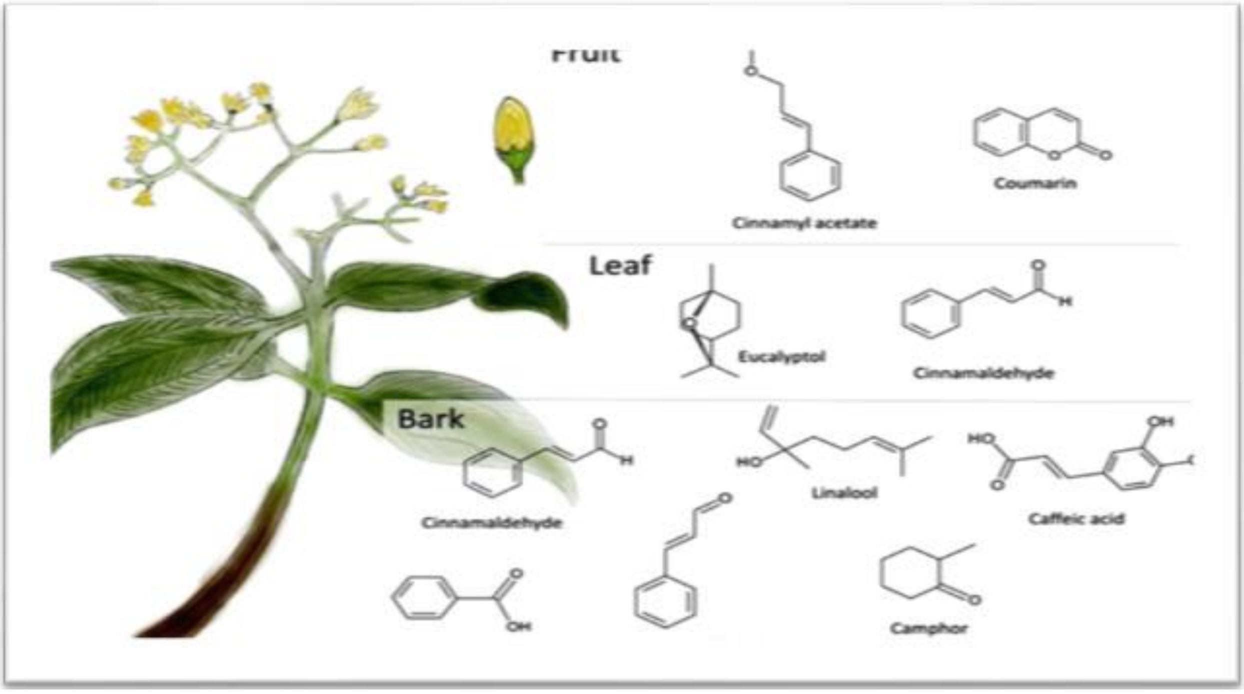

Fig 4 Chemical Constituents in Various Parts of the Cinnamon Plant (adopted from Błaszczyketal).

B. Chemical Test

The following tests can be conducted to identify specific compounds in cinnamon oil:

➢ *Test with Ferric Chloride*

- Dissolve a drop of cinnamon volatile oil in 5 ml of alcohol.
- Take a drop of ferric chloride into the solution.
- If cinnamic aldehyde is present, a brown color will be observed.
- If eugenol is present, a blue color will be observed [25].

➢ *Test with Phenylhydrazine Hydrochloride*

- Treat the alcoholic extract of cinnamon oil with phenylhydrazine hydrochloride.
- If cinnamic aldehyde is present, a red color will be produced due to the formation of the phenylhydrazone of cinnamic aldehyde [25].
- It is important to note that these tests are specific for identifying cinnamic aldehyde and eugenol in cinnamon

oil. Proper attribution and citation should be provided for the source of these tests (reference [25])

- *Traditional uses of Cinnamon*

- Cinnamon not only serves as a spice and flavoring agent but is also commonly added to chewing gums for its refreshing effect on the mouth and its ability to combat bad breath. Additionally, cinnamon may contribute to improved colon health, potentially reducing the risk of colon cancer.
- Cinnamon possesses coagulant properties, which can help prevent bleeding. Furthermore, it has been found to enhance blood circulation in the uterus and promote tissue regeneration. While cinnamon is widely recognized as a spice, its essential oils and other components also exhibit significant activities, including antimicrobial, antifungal, antioxidant, and antidiabetic effects.
- Cinnamon is utilized traditionally for its anti-inflammatory, nematicidal, mosquito larvicidal, insecticidal, antimycotic, and anticancer properties.
- Traditionally, cinnamon is used as a tooth powder and in the treatment of toothaches, dental problems, oral microbiota issues, and bad breath.

C. Pharmacological Activity of Cinnamon

- *Anti-oxidant activity*

Antioxidant compounds play a crucial role in protecting human health by combating oxidative stress and are commonly used in fats, oils, and food processing to prevent spoilage [26, 27]. Cinnamon, among other spices and medicinal plants, has been recognized as a potential source of beneficial antioxidants with potential health benefits against various diseases. Cinnamomum tamala has shown promising antioxidant activities in diabetic rats, while Cinnamomum osmophloeum, a Taiwanese species, has demonstrated significant antioxidant activities in vitro and in vivo under oxidative stress conditions. Extensive studies have been conducted on the antioxidant properties of Cinnamomum zeylanicum (cinnamon) using various methods. Furthermore, cinnamon has been investigated for its preservative properties in food products such as cakesCinnamaldehyde (E), the main compound extracted from Cinnamomum cassia, is known for its antityrosinase activity. Tyrosinase inhibitors, including cinnamaldehyde, have gained attention due to their ability to suppress hyperpigmentation and undesirable browning effects in mushrooms, fruits, and vegetables when exposed to sunlight or air. As a result, these inhibitors have found applications in cosmetics, medicine, and the food industry.

- *Anti-Inflammatory Activities*

Multiple research studies have highlighted the anti-inflammatory properties of cinnamon and its essential oils. These studies have identified various flavonoid compounds, such as gossiping, encephalin, hesperidin, bifolio, hypocretin, orexin, and quercetin, which exhibit anti-inflammatory activities [28]. A recent study discovered that 2'-hydroxy cinnamaldehyde, obtained from Cinnamomum cassia bark, demonstrated inhibitory effects on nitric oxide production by blocking the activation of nuclear factor kappa-light-chain-enhancer of activated B cells (NF-κB). This suggests that this compound has the potential to be an anti-inflammatory agent. Additionally, the ethanolic extract of Cinnamomum cassia showed significant anti-inflammatory effects Antioxidant compounds are essential for safeguarding human health as they combat oxidative stress. They are commonly used in fats, oils, and food processing to prevent spoilage [26, 27]. Cinnamon, along with other spices and medicinal plants, is considered a valuable source of beneficial antioxidants that may offer health advantages against various diseases. In the context of specific cinnamon species, Cinnamomum tamala has demonstrated promising antioxidant activities in diabetic rats. Meanwhile, Cinnamomum osmophloeum, a Taiwanese species, has shown significant antioxidant activities in both laboratory studies and living organisms under conditions of oxidative stress. Numerous studies have extensively examined the antioxidant properties of Cinnamomum zeylanicum (common cinnamon) using various research methods. Additionally, cinnamon has been explored for its potential as a preservative in food products like cakes. Recent research has focused on utilizing pectin film coated with cinnamon leaf extract, which has exhibited potent antioxidant and antibacterial activities. Cinnamaldehyde (E) is the primary compound extracted from Cinnamomum cassia and is renowned for its antityrosinase activity. Tyrosinase inhibitors, including cinnamaldehyde, are of interest due to their ability to suppress hyperpigmentation and undesirable browning effects in mushrooms, fruits, and vegetables when exposed to sunlight or air. As a result, these inhibitors have found applications in cosmetics, medicine, and the food industry. In summary, cinnamon and its various species have been recognized for their potential health benefits, especially as sources of antioxidants, and their applications in preserving food and inhibiting undesirable effects like hyperpigmentation. Moreover, compounds like cinnamaldehyde have specific roles in inhibiting tyrosinase and finding practical use in different industries. reducing the activation of Src/spleen-tyrosine-kinase-mediated NF-κB signaling [28].

- *Antidiabetic Activity*

A substance found in cinnamon has been identified as "insulin-potentiating factor" (IPF). The anti-diabetic properties of cinnamon bark have been demonstrated in studies conducted on diabetic rats induced by streptozotocin. These studies have shown that cinnamon extracts not only reduce blood glucose levels but also lower cholesterol levels [30]. Researchers, such as Anderson et al., have isolated and characterized polyphenol type-A polymers from cinnamon, which have been identified as insulin-like molecules. Another compound called a naphthalene methyl ester, derived from hydroxycinnamic acid derivatives, has been discovered and shown to lower blood glucose levels, further supporting the anti-diabetic properties of cinnamon [30]. In a recent study focusing on the linalool chemotype of cinnamon, appropriate doses of cinnamon (5, 10, and 20

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mg/kg) were found to improve glycemic control in individuals with diabetes by enhancing insulin secretion. It is believed that this improvement in glycemic control may be due to the reduction of oxidative stress and the proinflammatory environment in the pancreas, which could potentially protect pancreatic β cells. However, more research is needed to fully understand the mechanisms underlying these effects [31].

➢ *Antimicrobial Activity*

A specific substance found in cinnamon has been isolated and termed "insulin-potentiating factor" (IPF). The antidiabetic effects of cinnamon bark have been demonstrated in diabetic rats induced by streptozotocin. Numerous studies have indicated that cinnamon extracts lower blood glucose levels and reduce cholesterol levels [30]. These isolated polyphenol type-A polymers from cinnamon and detected these substances as insulin-like molecules. Additionally, a novel compound called naphthalene-methyl ester, derived from hydroxycinnamic acid derivatives, has been discovered and shown to have blood glucose-lowering effects, further supporting cinnamon's antidiabetic properties [30].In a recent study focusing on the linalool chemotype of cinnamon, appropriate doses of cinnamon (5, 10, and 20 mg/kg) were found to contribute to glycemic control in individuals with diabetes by enhancing insulin secretion. It is hypothesized that this improvement in glycemic control may be attributed to the amelioration of oxidative stress and the reduction of the proinflammatory environment in the pancreas, potentially offering protection to pancreatic β cells.

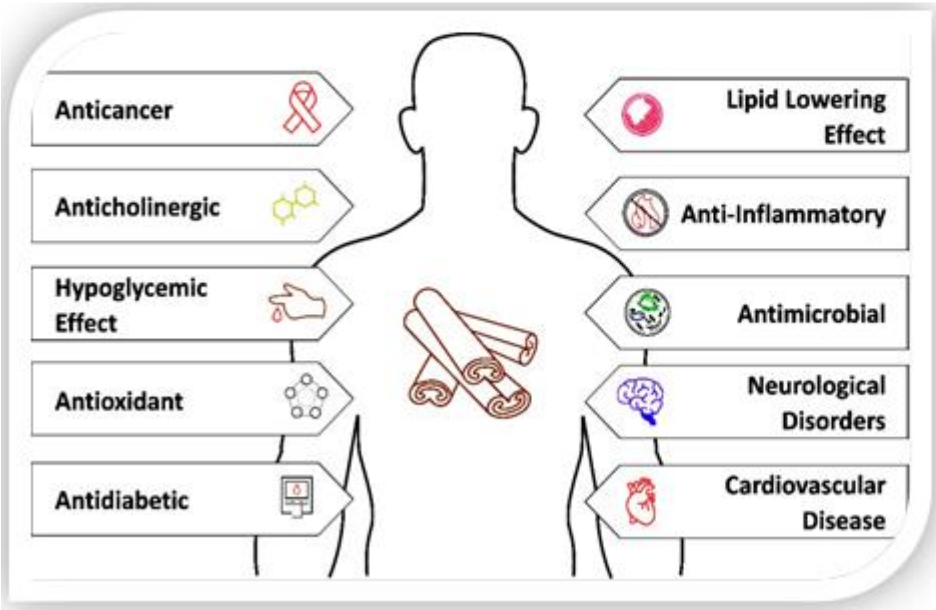

Fig 5 Cinnamon in the Treatment of Diseases and Disorders

➢ *Anticancer Activity*

The aqueous extract and procyanidins fraction of cinnamon have been found to inhibit the activity of vascular endothelial growth factor subtype 2 (VEGFR2) kinase, thereby inhibiting angiogenesis, which is involved in cancer development. This suggests that cinnamon could potentially be used for cancer prevention. Cinnamaldehydes, synthesized from cinnamaldehyde, have also been tested as inhibitors of angiogenesis [32]. Cinnamic aldehyde has been reported to inhibit the activity of NF-κB and the production of tumor necrosis factor-alpha (TNFα)-induced interleukin-8 (IL-8) in cells, further supporting the potential anticancer properties of cinnamic acid. Trans-cinnamaldehyde from Cinnamomum osmophloeum has been found to inhibit tumor cell growth and enhance tumor cell apoptosis [32]. A preliminary study conducted on Swiss albino mice investigated the effects of cinnamon and cardamom extracts on azoxymethane (AOM)-induced colon cancer. The treatments of aqueous extracts of cinnamon and cardamom resulted in increased activities of the detoxifying and antioxidant enzyme glutathione-S-transferase (GST) and lower levels of lipid peroxidation compared to the control group. Essential oils extracted from Cinnamomum cassia have also shown inhibitory effects on melanin production induced by alpha-melanocyte-stimulating hormone, thereby suppressing oxidative stress in murine B16 melanoma cells [33].

➢ *Cardiovascular Diseases*

Cinnamic aldehyde and cinnamic acid, two compounds isolated from Cinnamomum cassia, have shown potential effects against myocardial ischemia, indicating that cinnamon could be used in the treatment of cardiovascular diseases [34]. Cinnamophilin, an important lignan isolated from Cinnamomum philippinensis, has been found to have thromboxane A2 (TXA2) receptor-blocking activity and acts as a potential thromboxane synthase inhibitor and TXA2 receptor antagonist. This suggests that cinnamophilin could be helpful in the treatment of diseases involving TXA2 disorders, such as platelet aggregation and certain cancers. It mainly inhibits thromboxane receptor-mediated vascular smooth muscle cell proliferation, potentially making it useful in the prevention of vascular diseases and atherosclerosis [34]. Cinnamaldehyde has been shown to produce hypotensive effects, possibly due to peripheral vasodilation, as observed in anesthetized dogs and guinea pigs. The vasodilation induced by cinnamaldehyde in dogs lasted and remained over the recovery period, returning blood pressure to baseline levels. In rats, cinnamaldehyde has been found to expand vascular smooth muscle in an endothelium-independent manner, possibly by impeding both calcium influx and release. Cinnamaldehyde has also been shown to prevent the progression of hypertension in types 1 and 2 diabetes by reducing vascular contractility and exerting an insulinotropic effect in insulin deficiency [34].

➢ *Cholesterol- and Lipid-Lowering Effects*

Cinnamic aldehyde and cinnamic acid, two compounds isolated from Cinnamomum cassia, have also exhibited promising effects against myocardial ischemia. This indicates that cinnamon could have potential applications in the treatment of cardiovascular diseases [34].

Cinnamophilin, an important lignan derived from Cinnamomum philippinensis, has been identified as a blocker of thromboxane A2 (TXA2) receptors and a potential inhibitor of thromboxane synthase. By acting as a TXA2 receptor antagonist, cinnamophilin shows promise in the treatment of disorders related to TXA2, such as platelet aggregation and certain cancers. Moreover, it mainly inhibits thromboxane receptor-mediated vascular smooth muscle cell proliferation, suggesting it could be beneficial in preventing vascular diseases and atherosclerosis [34]. Cinnamaldehyde has been observed to produce hypotensive effects, likely attributed to peripheral vasodilation, as demonstrated in anesthetized dogs and guinea pigs. The vasodilation induced by cinnamaldehyde in dogs was sustained during the recovery period, leading to the return of blood pressure to baseline levels. In rats, cinnamaldehyde has been found to expand vascular smooth muscle in an endothelium-independent manner, possibly by impeding both calcium influx and release. Additionally, cinnamaldehyde has shown the potential to inhibit the progression of hypertension in type 1 and 2 diabetes by reducing vascular contractility and exerting an insulinotropic effect in cases of insulin deficiency [34]. In summary, compounds derived from Cinnamomum cassia and Cinnamomum philippinensis, such as 2-methoxycinnamaldehyde, cinnamic aldehyde, cinnamic acid, and cinnamophilin, have shown various cardiovascular benefits. These include reducing the expression of VCAM-1, potentially alleviating I/R injury, exhibiting effects against myocardial ischemia, blocking TXA2 receptors, and inducing vasodilation, making them promising candidates for potential treatments of cardiovascular diseases and related conditions.

➢ *Advanced Glycation End Products (AGEs)*

Cinnamon contains various phenolic and flavonoid compounds, some of which have been isolated and studied. Among these compounds, epicatechin, catechin, and procyanidin B2 have shown significant inhibitory activities on the formation of advanced glycation end products (AGEs). The antiglycation effects of these phenolic compounds are attributed not only to their antioxidant properties but also to their ability to trap reactive carbonyl species, such as methylglyoxal (MGO), which is an intermediate in AGE formation. Inhibiting AGE formation by trapping reactive carbonyl species could be a promising therapeutic approach for treating diabetes and its complications [36].

➢ *Insecticidal Effect*

Cinnamon essential oil (EO) and extract have demonstrated strong insecticidal properties. In the case of the bean weevil, Acanthoscelides obtectus, cinnamon EO was used on beans and showed a dose-dependent decrease in the growth rate of the weevils. However, its insecticidal activity diminished over time. Cinnamomum cassia bark, in both its methanolic extract and oil form, exhibited potent insecticidal activities against two other pests, Sitophilus oryzae, and Callosobruchus chinensis. The insecticidal effects were achieved through direct contact application and fumigation methods within one day after treatment. Cinnamon oils were found to be more effective when used in closed containers compared to open ones. In the case of termite control, Cinnamomum zeylanicum EO showed good efficiency against Odontotermes assamensis Holmgren. The termiticidal activity was attributed to the phenol constituents, which exhibited the strongest effects, followed by the alcohol, acetate, and aldehyde groups. Both Cinnamomum Diebold (root bark) and Cinnamomum cassia (bark) extracts were reported to be potent insecticidal agents. When used as fumigants, Cinnamomum cassia oil (bark) achieved 100% mortality within four hours after treatment in closed containers. The oil likely exerts its toxicity by penetrating the insect body through the respiratory system. In summary, cinnamon essential oil and extracts have shown significant insecticidal properties against various pests, including the bean weevil, Sitophilus oryzae, Callosobruchus chinensis, and termites. Their insecticidal effects can vary depending on the application method and the type of container used. These findings highlight the potential of cinnamon-based products as natural and effective alternatives for insect pest control.

D. Marketed Products

It is one of the ingredients of the preparations known as Rumalaya gel, Koflet lozenges, Chyavanprash (Himalaya Drug Company), Garbhapal ras, Sutsekhar ras (Dabur), and Sage Staminex capsules (Sage Herbals). This product is mentioned in the following table 4 with their company name.

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Table 4 Cinnamon-Containing Marketed Products

Brand name	Company Name	Image of product
Rumalaya gel	Himalaya	
Koflet lozenges	Himalaya	
Chyavanprash	Himalaya Drug Company	
Garbhapal ras	Baidyanath	
Sutsekhar ras	Dabur	
Sage Staminex capsules	Sage Herbals	

E. Current Industrial Application

Cinnamon essential oil (EO) is known to possess various active functions and compounds that make it attractive to the food, cosmetic, and pharmaceutical industries. Some of its notable functions include antioxidant, anti-inflammatory, anticancer, and antimicrobial activities [38, 39].Throughout history, cinnamon has been used worldwide in food preparations and traditional medicine for various purposes. It has been employed in the treatment of conditions such as diarrheal, gastrointestinal, and colonic diseases, as well as toothaches, oral infections, and acne.

In recent times, there has been a growing trend in the food and cosmetic industries to move away from synthetic preservatives due to their adverse effects on human health [38, 39]. As a result, natural alternatives like cinnamon EO are being considered for their potential preservative properties and other beneficial effects. The antioxidant, anti-inflammatory, anticancer, and antimicrobial activities of cinnamon EO make it an appealing option for these industries, offering potential benefits for product formulation and human health.

➢ *Future Industrial Applications:*

An aqueous extract of Cinnamomum species that demonstrates enhanced insulin-potentiating activity is the subject of US patent 6200569 B1. Another patent, US 20060073220 A1, focuses on cinnamon extracts enriched with total polyphenols, while WO 2012177958 A1 describes a pesticide containing cinnamon oil.

Due to their antimicrobial and antioxidant properties, natural aromatic plant extracts and essential oils have gained attention for use in active packaging, as they are not associated with negative health effects like synthetic additives. EP 2025620 A1 describes a patent for active packaging that inhibits food pathogens, utilizing a formulation of paraffin and natural plant extracts.

CinSulin® is a commercial drug available in capsule form that is based on an aqueous extract of cinnamon. It aids in maintaining healthy blood sugar levels within the normal range. Each capsule contains 250 mg of concentrated cinnamon bark extract, where desirable compounds are concentrated while unwanted substances are largely removed.

The antimicrobial effectiveness of cinnamon essential oil was tested against foodborne pathogens L. monocytogenes and E. coli by Mattos de Oliveira, Brugnera, do Nascimento, Batista, and Piccoli (2012), demonstrating its potential as a natural substance for controlling bacteria in foods [40]. Manos, Cacho-Nerin, Becerril, and Nerín (2013) also confirmed the efficiency of cinnamon essential oil against A. flavus.

Recognized as Generally Recognized as Safe (GRAS) by the FDA (Food & Drug Administration) (FDA, 2015), the cinnamon essential oil can be applied in various ways in food packaging or directly in food to add flavor or protect against microorganisms or oxidation.

Espitia et al. (2012) demonstrated the efficiency of cinnamon essential oil sachets as part of an antifungal packaging system for postharvest preservation of papaya fruit. The future application of cinnamon essential oil with new technologies such as nanomaterials is also being explored. Hu, Wang, Xiao, and Bi (2015) investigated the effect of chitosan nanoparticles loaded with cinnamon essential oil to preserve pork meat against lipid oxidation and microorganisms.

Peng and Li (2014) found that chitosan film incorporated with essential oils of lemon, cinnamon, and thyme (alone and in combination) exhibited antimicrobial activities. In their study, thyme essential oil showed greater antimicrobial capacity than cinnamon essential oil against the bacteria E. coli and S. aureus (Peng & Li, 2014). Wenet al. (2016) developed an antimicrobial polylactic acid (PLA) nanofilm incorporated with cinnamon essential oil using electrospinning. The authors concluded that this technique was more effective than traditional casting techniques as it maintained volatile antimicrobial agents in the nanofilm, thereby enhancing the antimicrobial activity. The nanofilm exhibited excellent antimicrobial activity against both Gram-positive and Gram-negative bacteria [41].

VI. CONCLUSION

Numerous studies have provided evidence for the presence of biologically active compounds in cinnamon, particularly cinnamaldehyde. These bioactive compounds have shown the potential to affect the human body in various ways and could be utilized in the treatment of a wide range of diseases and metabolic disorders. Cinnamon has demonstrated antimicrobial, antidiabetic, hepatoprotective, neuroprotective, cardioprotective, immunomodulatory, and anticancer properties. Its antioxidant and antimicrobial activities suggest its potential as a microbial-killing agent. Furthermore, the anti-inflammatory and antidiabetic properties of these compounds indirectly impact receptor-mediated mechanisms. Recent research has even indicated the possibility of cinnamon's application in reducing COVID-19 symptoms and strengthening the immune system for preventive treatment. Cinnamon finds application in different industries, taking various forms such as whole, ground, extract, or essential oil. In the pharmaceutical industry, cinnamon can be utilized as a therapeutic drug. The food industry can benefit from cinnamon's flavoring, antimicrobial, and antioxidant properties, incorporating it into products such as chicken, meat, fish, and salad. Moreover, cinnamon can be incorporated into food packaging as an active agent, such as in sachets or as a coating in polymer matrices. Additionally, the cosmetic industry can make use of cinnamon's properties. While there is already significant evidence supporting the health benefits of cinnamon, further in vivo and clinical studies are necessary. These studies will aid in better understanding the mechanisms of action, assessing potential therapeutic uses, and evaluating possible interactions with foods and drugs. This research is crucial for developing an appropriate form and route of administration of cinnamon to maximize its therapeutic effects In conclusion, cinnamon, as an everyday spice, has been shown to possess numerous potential health benefits. Its inclusion in daily diets is recommended. However, further research should focus on optimizing the form and route of administration of cinnamon to maximize its therapeutic effects.

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