Cinnamon as Useful Preventive Substance

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Cinnamon is widely used as a food spice, but due to its antibacterial and pharmacological properties, it can also be used in processing, medicine and agriculture. The word "Cinnamon" can refer to the plant, processed material, or an extract. It is sometimes used as a substance, and sometimes used as a mixture or as compounds or a group. This article reviews research into the effectiveness of various forms of cinnamon for the control of plant diseases and pests in crops and during storage of fruit and vegetables. Cinnamon acts on pests mainly as a repellent, although in higher doses it has a biocidal effect and prevents egg-laying. Cinnamon and its compounds effectively hinder bacterial and fungal growth, and the phytotoxic effects of cinnamon make it a possible herbicide. This article presents the wide practical use of cinnamon for various purposes, mainly in agriculture. Cinnamon is a candidate for approval as a basic substance with protective potential. In particular, it can be used in organic farming as a promising alternative to chemical pesticides for use in plant protection, especially in preventive treatments. The use of natural products is in line with the restriction of the use of chemical pesticides and the principles of the EU's Green Deal.

basic substance | human health | plant protection activity | organic farming

1. Introduction

Cinnamon (*Cinnamomum zeylanicum* L. and *Cinnamon cassia* L.), a species of the *Lauraceae* family, is an evergreen tree of the tropics, which is widely used in medicine, and offers a rich variety of applications worldwide. The word was adopted by English towards the end of 14th century as a loanword from the old French "cinnamone", which in term came from Latin via the Greek-Phoenician word "kinnamomon" and supposed to be from Semitic cf. Hebrew "qinamon". The first appearance of the word in print dates to 1430, in John Lydgate Bochas' "Fall of Princes" [1].

Cinnamon contains manganese, iron, dietary fibre, and calcium. It has derivatives, such as cinnamaldehyde (CNAD), cinnamic acid, cinnamate, and many other ingredients, such as polyphenols and antioxidants, with anti-inflammatory, antidiabetic, antimicrobial, and anticancer properties. Several reports have shown numerous properties of cinnamon in the form of bark and bark powder. Essential oils and phenolic compounds in cinnamon contribute positively to human health. Studies have recently shown the positive influence of cinnamon in the treatment of Alzheimer's disease, diabetes, arthritis, and arteriosclerosis [2].

Wang et al. [3] reported other major compounds in cinnamon: coumarin, cinnamyl alcohol, cinnamaldehyde, cinnamic acid, eugenol, and cinnamyl acetate [3]. Tung et al. [4] have also reported the presence of a wide range of essential oils in cinnamon, such as *trans*-cinnamaldehyde, cinnamyl acetate, eugenol, l-borneol, caryophyllene oxide, b-caryophyllene, l-bornyl acetate, E-nerolidol, α-cubebene, α-terpineol, terpinolene, and α-thujene. Cinnamon consists of a variety of resinous compounds (**Table 1**).

Table 1. Various chemical constituents of the cinnamon plant [5].

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%)
Buds (*C. zeylanicum*)	Terpene hydrocarbons: 78.00%
	α-Bergamotene: 27.38%
	α-Copaene: 23.05%
	Oxygenated terpenoids: 9.00%
Flowers (*C. zeylanicum*)	(*E*)-Cinnamyl acetate: 41.98%
	trans-α-Bergamotene: 7.97%
	Caryophyllene oxide: 7.20%

According to other sources, ground cinnamon contains carbohydrates, fibre, moisture, protein, fat, and ash. It also contains vitamins A, B, C, E, K, and lipids. The composition is different depending on the geographical origin and the processing methods [6][7].

As a plant, cinnamon contains many substances and substance groups. Among these, there are essential oils, diterpenes, catechins, proanthocyanidins, tanning agents, colouring agents, phenolic carboxylic acids, lignans, and mucins. Cinnamon's essential oils mainly have antifungal and antibacterial properties and, similarly to cinnamon bark extract, are characterized by antioxidant activity [8]. Moreover, essential oils have antiinflammatory, antidiabetic, antitumor, antimutagenic, and memory-enhancing properties. Cinnamaldehyde and eugenol are active components against Gram-positive and Gram-negative bacteria [9].

Sharifi-Rad et al., 2021 [10] showed that the bioactive compounds of *Cinnamomum* species possess antimicrobial, antidiabetic, antioxidant, anti-inflammatory, anticancer, and neuroprotective effects.

Incomplete knowledge about the safe consumption of higher doses of cinnamon on a daily basis makes it necessary to assess the occurrence of this risk, and therefore, the long-term use of a high amount of cinnamon should be monitored. The tolerable daily intake for coumarin (0.1 mg/1 kg body weight) can be regarded as safe in terms of daily cinnamon intake without the risk of adverse effects [11]. According to the scientific data currently available, a risk assessment must be focused on the problematic ingredients of cinnamon extract, especially on coumarin, *trans*-cinnamaldehyde, safrol, and styrene, which are toxic.

Cinnamon bark is obtained twice a year, closely following each of the rainy seasons, when the air humidity facilitates bark harvesting. The first harvest is done when the trees are three years old, a year after pruning. The side stems that are about three-years-old are cut off, and the bark is pulled off. Cinnamon bark is gained only from stems that are between 1.2 and 5 cm in diameter.

Cinnamon is often ground to a powder before sale. The powder should be packed in moisture-proof wrapping (polypropylene bags) to keep the flavour. Polyethylene packaging is not advisable, as the flavour components diffuse through it [12].

2. Culinary and Medicinal Use

Cinnamon bark is commonly used as a spice. It is principally used in cooking as a condiment and flavouring agent. It is used in the production of chocolate, especially in Mexico, which is the biggest importer of true cinnamon (*C. zeylanicum* L.). It is also added to desserts, such as apple pie, donuts, and cinnamon buns, as well as spicy candies, tea, hot cocoa, and liqueurs. True cinnamon and not cassia (*C. cassia* L.) is better for use in sweet dishes. In the Middle East, it is often used in savoury dishes of chicken and lamb. In the USA, cinnamon is often used as an additive to flavour cereals, bread-based dishes, and fruit, especially apples; and a cinnamon–sugar mixture is on sale in grocery stores. Another use of cinnamon is in pickling.

Cinnamon bark is one of the rare spices that can be consumed directly; cinnamon powder has long been an important spice in Persian cuisine, added to various thick soups, drinks, and sweets. It is often used as a mixture with rosewater or other spices to make a cinnamon-based curry for stews or just sprinkled on sweet desserts [13].

2.1. Effects in Humans

Cinnamaldehyde (CNAD) lowers inflammatory reactions, oxidative stress, and apoptosis of the liver in *Salmonella typhimurium*-infected mice. Supplementation of CNAD might be a good preventive method to alleviate the liver damage caused by *Salmonella typhimurium* infection in humans and animals [14]. Moreover, cinnamon bark essential oils (EOs) have been shown to cause oxidative stress to *Klebsiella pneumoniae*, resulting in the loss of cell viability [15]. Both oregano and cinnamon bark EOs have strong antibacterial properties. Aljaafari et al. [16] have shown that the antimicrobial properties of essential oils (EOs) are based on the mode of action in relation to membrane disruption, efflux inhibition, the increase in membrane permeability, and the decrease in intracellular

ATP. These essential oil compounds can be used as potential agents against bacteria, fungi, and viruses. In the future, the integration of EOs uses can lead to many clinical applications.

In medicine, the essential oils in cinnamon behave like other volatile oils. It has also been used in the treatment of digestive system problems and colds. The essential oils in cinnamon also have antimicrobial properties and are used as a preservative in some foods. Cinnamon has been reported to have remarkable pharmacological effects in the treatment of diabetes type 2 resistant to both mellitus and insulin; however, the plant material used in the study was mainly from cassia and only some of the plant material was from *C. zeylanicum*. Cinnamon has traditionally been used for toothache and to fight bad breath, and its regular use is thought to cure the common cold and support digestion [17]. It is noted that regular drinking of *C. zeylanicum* tea made from the bark could be helpful in oxidative-stress-related illness in humans, since it has considerable antioxidant potential. Cinnamon may also act as an aphrodisiac. One teaspoon of cinnamon has as many antioxidants as a cup of pomegranate juice and half a cup of blueberries [17].

Nanocapsules with cinnamon-thyme-ginger composite essential oils prepared with chitosan as the wall via ionic gellification reaction were tested in medicine and revealed durable antibacterial activity against *Escherichia coli*, *Bacillus subtilis*, and *Staphylococcus aureus*. Composite essential oil nanocapsules CEO-NPs can be applied as a strong long-lasting natural preservative [18].

2.2. Adverse Effects Reported in Humans

Scientific research has confirmed the effectiveness of cinnamon in fighting microbes, viruses, fungi, oxidants, tumours, and hypertension. It also has antidiabetic, gastro-protective, and immune modulatory potential [17]. However, the popular use of cinnamon has also resulted in several reports of side effects from its short- and long-term use. The most common negative effects were disorders of the stomach and bowels, as well as allergic reactions, which were self-controlling in most cases. Although cinnamon is safe as a spice and/or flavour, prolonged and enlarged use may be a health risk, and hence, in medicinal uses, it should be clinically monitored [19].

Cinnamon coats and dries the mouth and throat, leading to coughing, gagging, vomiting, and the inhalation of cinnamon, causing throat irritation, breathing difficulties, and a risk of pneumonia or lung collapse [20][21]. Cinnamon contact stomatitis (CCS) is also a sporadic reaction to the consumption of foods containing artificial cinnamon flavour. Physicians who treat patients with oral conditions ought to be aware of CCS to correctly diagnose and manage this condition [22]. Contact stomatitis, which is related to the use of cinnamon flavourings, is rather rare. The symptoms, as well as the histopathologic features of this disease are non-specific. They may be similar to other inflammatory illnesses of the oral mucosa, which causes problems in diagnosis. Patients develop white and erythematous spots of rapid occurrence, with an associated sensation of burning. High levels of coumarin and cinnamaldehyde might be associated with mouth sores [23]. High levels of coumarin and cinnamaldehyde might be also correlated to liver damage and low blood sugar [24]; such high levels may increase the risk of cancer, breathing problems, and interaction with certain medications [11].

Oral lesions caused by a reaction to cinnamon flavouring agents are rather uncommon and are probably unrecognized by many physicians. Most patients feel a “burning sensation”, which is the primary symptom. Clinically, lesions present as erythematous patches with different degrees of superimposed keratosis or ulceration. The lesions are usually limited to the buccal mucosa and lateral border of the tongue. The responsible agent was most frequently cinnamon-flavouring chewing gum, and symptoms usually eased within 1 to 2 days after the last use of the product containing cinnamon [25].

3. Agricultural Purpose

Cinnamon oils and extracts possess antifungal properties against serious plant diseases (**Table 2**). Wilson et al. [26] indicated that, out of 49 essential oils tested, cinnamon leaf *C. zeylanicum* showed the strongest antifungal activity against *Botrytis cinerea*. Montes-Belmont and Carvajal [27] found that *Aspergillus flavus* was fully inhibited by *C. zeylanicum*. In other studies, *C. zeylanicum* proved to be fungicidal towards pathogens (*Colletotrichum musae*, *Lasiodiplodia thebromae*, and *Fusarium proliferatum*) isolated from bananas [28]. Cinnamon also had an antifungal effect against *Oidium murrayae* [29] and harnessed conidial germination of *Colletotrichum gloesporioides* [30]. In in vitro tests, it proved to have a significant mycelial inhibition in corn rot *Fusarium oxysporum* f. sp. *gladioli* [31] and to be very effective against the growth of *Rhizoctonia solani* [32]. Moreover, cinnamon has powerful antifungal activity towards early tomato blight (*Alternaria solani*) [33]. *Botrytis cinerea* is a serious problem, especially in horticultural crops. The investigations of Wang et al. [34] demonstrated that cinnamon microemulsions possessed high in vivo control properties against gray mould of pears, *B. cinerea.* The influence of *C. zeylanicum* organic powder on the growth of *B. cinerea* and its effect on tomato plants have also been assessed. Cinnamon bark powder and also its water suspensions and filtrates controlled *B. cinerea*; moreover, tomato plants sprayed with cinnamon developed better than the control plants [35].

Table 2. Selected examples of fungicidal activity of cinnamon components for agricultural purposes.

Pathogen	Form of Cinnamon	Effective Dose	Reference No.
Fusarium oxysporium	Essential oil	100–300 ppm	[31]
Botrytis cinerea	Extract *C. cassia*	20 mL/L	[36]
Fusarium verticillioides	Essential oil Cinnamon oil with cinnamaldehyde	60 µL/L 45–60 µL/L	[37]
Colletotrichum gloerpoides *Phytophthora palmivora* *Fusarium solani*	Essential oil	1000 µL/L	[38]
Sclerotinia sclerotiorum	Essential oil	10–500 ppm	[39]
Sclerotinia sclerotiorum	*C. cassia* oil	256 µg/mL of agar	[40]

Pathogen	Form of Cinnamon	Effective Dose	Reference No.
Sclerotinia scleriotiorum *Aspergillus* sp.	*C. cassia* oil	1.5 mL/L	[40]
Lasidiplodia theobromae *Colletotrichumgloerpoides* *Alternaria citrii*	Essential oil	1000 µL/L	[41]
Colletotrichum musae *Lasidiplodia theobromae*	Cinnamon extract	5 g/L	[42]
Sclerotinia sclerotiorum	ethyl acetate cinnamon extract	2 g/L	[43]

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