ISSN: 2643-671X

Review Article

Journal of Agriculture and Horticulture Research

Cinnamon as Traditional and Modern Medicine

Muhammad Arshad Ullah[1*], Ali Hassan[2]

[1]*Pakistan Agricultural Research Council, Islamabad, Pakistan*

[2]*PMAS- University of Arid Agriculture, Rawalpindi, Pakistan*

[*]Corresponding Author:
Muhammad Arshad Ullah, Pakistan Agricultural Research Council, Islamabad, Pakistan.

Submitted: 21 Nov 2022; **Accepted**: 28 Nov 2022: **Published**: 31 Dec 2022

Citation: Muhammad Arshad Ullah, Ali Hassan (2022). Cinnamon as Traditional and Modern Medicine, *J Agri Horti Res*, 2022, 5(2), 141-150.

Abstract

Cinnamomum is a middle sized evergreen tree, about 10-15 m tall, innate to Southern India and Sri Lanka, but also is found in central to Burma, southern mainland China, Cambodia, Malaysia, Taiwan and Indonesia. In brief, the tree is dispensed in regions between 500 and 1500 m in height. Cinnamon, a plant of the laurel species Lauraceae, as a spice in numerous cultures for centuries, has been consumed in China for thousands of years against many diseases, for instance the "thirsty disease," which was an old expression for diabetes in China before the expression diabetes mellitus was created in modern medicine.

The constituents of procyanidins contain both procyanidin A-type and B-type bonds. These procyanidins are taken out from cinnamon and berries. They also own antioxidant activities. In the same way, the most important ingredients of cinnamon is trans-cinnamaldehyde or cinnamaldehyde which exists in the essential oil, therefore donating to the fragrance and to the diverse biological activities perceived with cinnamon. Essential oil from cinnamon leaves includes a high level of cinnamon. Subsequently, C. osmophloeum is also used as a replacement spice for C. cassia. One of the main constituents of essential oil obtained from C. zeylanicum termed (E)-cinnamaldehyde has an antityrosinase activity, whereas cinnamaldehyde is the main compound accountable for this activity. Utilization of cinnamon (short term) is related with a notable decrease in systolic Blood Pressure (BP) and diastolic BP. Even though cinnamon exhibits hopeful influences on BP-dropping potential, it would be premature to advise cinnamon for BP control owing to the limited number of investigations available. Its bark has been extensively used as a flavoring and spice agent for periods. Cinnamon has been suggested to have many pharmacological attributes, containing antimicrobial effects and antioxidant activity. Cinnamomum zeylanicum (CZ) extracts on diabetes demonstrates numerous beneficial effects. CZ reduced total cholesterol, LDL choles-terol and triglycerides while increasing HDL-cholesterol in diabetics.

The essential oils obtained from the bark of CZ and eugenol has shown very powerful activities, decreasing 3-nitrotyrosine formation and inhibiting the peroxynitrite-induced lipid peroxidation in in-vitro assays. The volatile oils of CZ have shown 55.9% and 66.9% antioxidant activity at 100 and 200 ppm concentration, respectively. The dried fruit extracts of CZ with ethyl acetate, acetone, methanol and water exhibited antioxidant activity in the order of water > methanol > acetone > ethyl acetate. CZ bark extracts were found to be potent in free rad-ical scavenging activity especially against DPPH radicals and ABTS radical cations, while the hydroxyl and super-oxide radicals were also scavenged by the tested compounds. CZ has 65.3% of anti-oxidant ac-tivity and strong free radical scavenging activity. Treatment of 54 healthy volunteers with CZ 100 mg/30ml of tea daily were significantly effective in the reduction of lipid peroxidation and increasing TAP and TTM in comparison with controls. Cinnamon bark extract entrapped in nanoparticles prepared with poly-DL-lactide-co-glycolide (PLGA), a biocompatible polymer widely used in the pharmaceutical industry and which could be used in the food industry to deliver antimicrobial compounds to food matrices. Cinnamon (Cinnamomum zeylanicum) bark essential oil (CBEO) has been used for thousands of years in Ayurvedic medicine to soothe aching joints and numb pain. It is still used for similar purposes in India, presumably because of its antiinflammatory property. CBEO typically contains a very high amount of cinnamaldehyde and a small amount of eugenol, among many other aromatic compounds. CBEO and cinnamaldehyde have been studied for their antibacterial, antifungal, anti-diabetic, anti-inflammatory, and anticancer activities. Furthermore, CBEO has gained popularity for use in skin care products; however, research on its effects on human skin is largely scarce.

Introduction

Cinnamon, a plant of the laurel species Lauraceae, as a spice in numerous cultures for centuries has been consumed in China for thousands of years against many diseases, for instance the “thirsty disease,” which was an old expression for diabetes in China before the expression diabetes mellitus was created in modern medicine [1,115]. On the whole, approximately 250 species have been recognized among the cinnamon genus, with trees being distributed all over the Earth [2]. The constituents of procyanidins contain both procyanidin A-type and B-type bonds [3]. These procyanidins are taken out from cinnamon and berries. They also own antioxidant activities [3]. In the same way, the most important ingredients of cinnamon is trans-cinnamaldehyde or cinnamaldehyde which exists in the essential oil, therefore donating to the fragrance and to the diverse biological activities perceived with cinnamon [4]. Equally important, in 2008, a study by Chang et al. (2008) on Cinnamomum osmophloeum demonstrated that the essential oil from cinnamon leaves includes a high level of cinnamon. Subsequently, C. osmophloeum is also used as a replacement spice for C. cassia [5]. One of the main constituents of essential oil obtained from C. zeylanicum termed (E)-cinnamaldehyde has an antityrosinase activity whereas cinnamaldehyde is the main compound accountable for this activity [6, 7]. Cinnamon has a long history of consumption in traditional medicine, but there are few evidences on its interacted pathophysiological mechanisms [8].The fresh cinnamon sticks are crushed to prepare tea, to cook into sprinkle on toast, desserts or cereal. Since it may act together with certain medicines, it is notable to check other drugs before using cinnamon [9].It can help relieve indigestion pain and toothaches. This creates it ideal for cooking and remedial use [10]. In the same way, cinnamon is a coagulant and stops bleeding (Hossein et al., 2013). It also enhances the blood circulation in the advances tissue renewal and uterus [11]. On the whole, this plant performs a key role as a spice, but its essential oils and other ingredients also have important activities, counting antifungal antimicrobial antidiabetic antioxidant anti-inflammatory antitermitic antimycotic nematicidal insecticidal mosquito larvicidal and anticancer activities [116,12-19]. It is the most significant modifiable risk agent for cerebrovascular, cardiovascular, and renal disease [20]. The relative risk assessment collaborating group has recognized hypertension as the leading worldwide risk agent for mortality and as the third leading risk agent for disease burden [21].These interventions contain dietary sodium reduction, weight loss, and physical activity, limitation in alcohol consumption, potassium supplementation and variation of whole diets [22].Therefore, the influence of dietary composition on BP is a subject of public health significance [23]. In 2011, Xue et al indicated that cinnamaldehyde increased rat vascular smooth muscle in an endothelium-independent method. The capability of cinnamaldehyde in vasodilatory performance might be due to inhibition of Ca2+invasion and Ca2+discharge [24].

Likewise, cinnamaldehyde prevents the development of hypertension in types I and II diabetes by reducing vascular contractility, as well as its insulinotropic effect in insulin fault [25]. Hypertension is very common in persons with T2DM, influencing up to 60% of the people [26]. Akilen et al. (2010) exhibited a significant decrease in systolic BP or diastolic BP followed by a considerable reduction in glycemic signs (fasting plasma glucose or HbA1c). Cinnamon has been reported to positively affect the insulin system [27]. Several combinations of essential oils counting cinnamon, fenugreek, cumin, and oregano have been exhibited to increase insulin sensitivity in vitro trials. Talpur et al. (2005) realized that the capability to alter systolic BP in rat models was the most sensitive primary index of insulin sensitivity [28]. Utilization of cinnamon (short term) is related with a notable decrease in systolic BP and diastolic BP. Even though cinnamon exhibits hopeful influences on BP-dropping potential, it would be premature to advise cinnamon for BP control owing to the limited number of investigations available. Therefore, a long-term, sufficiently powered randomized controlled trial (RCT) containing a larger number of patients is required to assess the clinical potential of cinnamon on BP regulator among patients with T2DM [29]. Cinnamomum is a middle sized evergreen tree, about 10-15 m tall, innate to Southern India and Sri Lanka but also is found in central to Burma, southern mainland China, Cambodia, Malaysia, Taiwan and Indonesia [30,31]. In brief, the tree is dispensed in regions between 500 and 1500 m in height. Its bark has been extensively used as a flavoring and spice agent for periods. Cinnamon has been suggested to have many pharmacological attributes, containing antimicrobial effects and antioxidant activity [32].

Numerous reports have distributed with the numerous attributes of cinnamon in the forms of, essential oils, bark, bark powder, flavonoids, phenolic compounds, and isolated constituents. Each of these attributes plays a vital role in the improvement of person’s health [33]. In spite of this, the exact BP-lowering procedure of cinnamon is still unknown and new studies are required to explain this issue [34]. In addition, agents associated with related disorders, containing stroke, Alzheimer’s disease, and cancer, have also been exhibited to be improved by cinnamon and its constituents in in vitro findings [35].

The volatile oils obtained from the bark, leaf, and root barks vary significantly in chemical composition, which suggests that they might vary in their pharmacological effects as well [36]. The different parts of the plant possess the same array of hydrocarbons in varying proportions, with primary constituents such as; cinnamaldehyde (bark), eugenol (leaf) and camphor (root) [42]. Thus cinnamon offers an array of different oils with diverse characteristics, each of which determines its’ value to the different industries. For example the root which has camphor as the main constitute, has minimal commercial value unlike the leaf and bark [37]. It is this chemical diversity that is likelyCZ, also known as Ceylon cinnamon (the source of its Latin name, zeylanicum) or ‘true cinnamon’ is indigenous to Sri Lanka and southern parts of India [37]. Three of the main components of the essential oils obtained from the bark of CZ are trans-cinnamaldehyde, eugenol, and linalool, which represent 82.5% of the total composition [38]. Transcinnamaldehyde, accounts for approximately 49.9–62.8% of the total amount of bark oil [39,40]. Cinnamaldehyde and eugenol are also the major components of CZ extracts [41].

The levels of coumarins in CC appear to be very high and pose health risks if consumed regularly in higher quantities. According to the German Federal Institute for Risk Assessment (BfR), 1 kg of CC (CC) powder contains approximately 2.1-4.4 g of coumarin, which means 1 teaspoon of CC powder would contain around 5.8-12.1 mg of coumarin [42]. This is above the Tolerable Daily Intake (TDI) for coumarin of 0.1mg/kg body weight/day recommended by the European Food Safety Authority (EFSA) [43]. The EFSA advocates against the regular, long term use of CC as a supplement due to its coumarin content [44]. In-vitro and in-vivo studies in animals and humans from different parts of the world have demonstrated numerous beneficial health effects of CZ, such as anti-inflammatory properties, anti-microbial activity, reducing cardiovascular disease, boosting cognitive function and reducing risk of colonic cancer [45].

A recent meta-analysis by Ranasinghe, et al. and a system-atic review by Bandara et al., on the effects of CZ extracts on diabetes demonstrates numerous beneficial effects both invitro andin-vivo [46]. Hasan et al. (2012), also confirmed these effects and dem-onstrated that CZ reduced total cholesterol, LDL choles-terol and triglycerides while increasing HDL-cholesterol in diabetic rats. Similar results have also been observed in hyper-lipidaemic albino rabbits (Javed et al., 2012). Nyadjeu et al. (2011) examined the effects of CZ extracts (CZA) on mean arterial blood pressure (BP) of normotensive (NR) rats, salt-loaded hypertensive rats (SLHR), L-NAME hypertensive rats (LNHR) and spontaneously hypertensive rats (SHR).

The essential oils obtained from the bark of CZ and eugenol has shown very powerful activities, decreasing 3-nitrotyrosine formation and inhibiting the peroxynitrite-induced lipid peroxidation in in-vitro assays [47]. The volatile oils of CZ have shown 55.9% and 66.9% antioxidant activity at 100 and 200 ppm concentration, respectively [48]. The dried fruit extracts of CZ with ethyl acetate, acetone, methanol and water exhibited antioxidant activity in the order of water > methanol > acetone > ethyl acetate [49]. A. Kitazuru, et al. (2004) studied the effects of ionizing radiation on natural CZ antioxidants and showed that irradiation in the dose range applied did not have any effect on the anti-oxidant potential of the cinnamon compounds.

CZ bark extracts were found to be potent in free rad-ical scavenging activity especially against DPPH radicals and ABTS radical cations, while the hydroxyl and super-oxide radicals were also scavenged by the tested com-pounds (Mathew and Abraham, 2004). Similar findings were noted by Prakash, et al. (2007) who showed that CZ has 65.3% of anti-oxidant ac-tivity and strong free radical scavenging activity [39]. Ranjbar et al. (2006) treated 18 operating room personnel with CZ (100 mg/300 mL tea) daily for 10 days and blood samples were analyzed for biomarkers of oxidative stress biomarkers including Lipid Peroxidation Level (LPO), Total Antioxidant Power (TAP) and Total Thiol Molecules (TTM). Treatment of 54 healthy volunteers with CZ 100 mg/30ml of tea daily were significantly effective in the reduction of lipid peroxidation and increasing TAP and TTM in com-parison with controls [50].

An aqueous extract of CZ is known to inhibit tau aggre-gation and filament formation, which are hallmarks of Alzheimer's disease [51]. Takasao et al. (2012) demonstrated that CZ extracts facilitates collagen biosynthesis in human dermal fibroblasts. CZ extract up-regulated both mRNA and protein expression levels of type I collagen without cyto-toxicity; cinnamaldehyde was the major active compo-nent promoting the expression of collagen by HPLC and NMR analysis. This suggests that CZ extracts might be useful in anti-aging treatment of skin [52]. CZ extracts have also exhibited the strong inhibitory effects on osteoclastogenesis [53]. CZ dose-dependently inhibited osteoclast-like cell formation at concentrations of 12.5-50µg/ml without affecting cell viability. This finding raises prospects for the development of a novel approach in the treatment of osteopenic diseases [53]. Other in-vivo effects in animals CZ is known to have anti-secretagogue and anti-gastric ulcer effects as shown by a study conducted by Alqasoumi (2012). Rao and Lakshmi (2012)induced diar-rhoea in mice using the magnesium sulphate-induced diarrhoea test and showed that CZ extracts at 100 and 200 mg/kg doses significantly reduced the extent of the diar-rhoea (71.7% and 80.4%) in test animals [54]. The CZ extracts served to ac-celerate the wound healing process and specifically in-creased epithelialisation [55]. In Wister rats CZ given orally increased the wound breaking strength significantly in incision wounds model and in dead space wounds the granulation tissue breaking strength and hydroxyproline content were significantly increased [56].

CZ has also been shown to have hepato-protective effects in a study where liver injury was induced in rats by CCl4 [57]. Water-based extract from CZ was a potent inhibitor of VEGFR2 kinase (Vascular Endothelial Growth Factor Receptor) activity which is involved in angiogenesis [58]. Domaracký et al. (2007) administered CZ for two weeks to female mice and evalu-ated the effects on the viability of embryos of mice, number of nuclei and the distribution of embryos according to nu-cleus number.

The average ED50from the first and second tests of the petroleum ether extract on these tumour cells were 60 and 24 pg/ml respectively and of the chloroform extract were 58 and 20 pg/ml respectively. Singh et al. (2009) investigated the cytotoxic effects of aqueous cinnamon extract from the bark of CZ on human and mouse cell lines.Cinnamon extracts are known to increase Tristetraprolin mRNA and protein levels, Tristetraprolins have anti-inflammatory effects due to destabilizing of pro-inflammatory mRNA [59].

The genus Cinnamomum (family Lauraceae) contains more than 300 evergreen aromatic trees and shrubs. Four species have great economic importance for their multiple culinary uses as common spices worldwide: Cinnamon zeylanicum Blume (a synonym of Cinnamon verum J. Presl, known as Sri Lanka cinnamon), Cinnamon loureiroi Nees (known as Vietnamese cinnamon), Cinnamon burmanni (Nees &T. Nees) Blume (known as Indonesian cinnamon) and Cinnamon aromaticum Nees (a synonym of Cinnamon cassia (L.). J. Presl, known as Chinese cinnamon) [60]. The term cinnamon commonly refers to the dried bark of C. zeylanicum and C. aromaticum used for the preparation of different types of chocolate, beverages, spicy candies and liquors [61,60]. Moreover, cinnamon is used in various savory dishes, pickles, soups, and Persian sweets. Cinnamon bark, leaves, flowers and fruits are used to prepare essential oils, which are destined for use in cosmetics or food products. Moreover, according to traditional Chinese medicine (dating roughly 4000 years), cinnamon has been used as a neuroprotective agent and for the treatment of diabetes [62,63]. Cinnamon has also been used as a health-promoting agent for the treatment of diseases such as inflammation, gastrointestinal disorders and urinary infections [64,65]. Another potential medical use of cinnamon would be with regards to its antimicrobial properties, especially antibacterial activity. It is well known that infection is one of the leading causes of morbidity and mortality worldwide. According to the World Health Organization reports, in 2011, there were more than 55 million deaths worldwide with infection being responsible for one-third of all deaths [66]. The high prevalence of infection and long-term exposure to antibiotics has lead to the antibiotic resistance of microorganisms. Therefore, much attention has been paido the discovery and development of new antimicrobial agents that might act against these resistant microorganisms, and cinnamon could be an interesting candidate [67,68]. It was used for embalming by the ancient Egyptian people [69]. During the Dutch occupation in the 17th century, cinnamon cultivation started in Java, and the East India Company became the main cinnamon exporter to European countries [69]. Although Ceylon cinnamon cultivation diminished, Sri Lanka remains the main source of cinnamon oils, and Ceylon cinnamon oil from Sri Lanka has been broadly used by both pharmaceutical and food industries. Pharmaceutical industries also use Chinese cinnamon oils [60,69]. The average production rate of cinnamon is about 27,500 to 35,000 tons per year [71]. Cinnamon has mainly been cultivated in Sri Lanka, Seychelles, Madagascar and China [60,70,71]. The application of fertilizer containing urea, phosphate, and potash is known to increase cinnamon production [71].

The main compounds isolated and identified in cinnamon (C. zeylanicum) belong to two chemical classes: polyphenols and volatile phenols. Among polyphenols, cinnamon contains mainly vanillic, caffeic, Gallic, protocatechuic, p-coumaric, and ferulic acids [72]. With regards to volatile components, the chemical composition of cinnamon essential oils depends on the part of the plant from which they are extracted. In bark essential oil, cinnamaldehyde is the most represented substance, with a content ranging from 90% to 62%–73%, depending on the type of extraction, this being higher for steam distillation than Soxhlet extraction [73]. In cinnamon leaf essential oil, the main component is eugenol, which reaches a concentration of more than 80%. In the essential oil obtained from cinnamon fruit and flowers, (E)-cinnamyl acetate and caryophyllene are the major components [74,75]. It also shows beneficial effects on oral health and is used for toothaches, oral infections, and to remove bad breathe [76]. Cinnamon has also been used to treat acne and melisma [77]. Moreover, it has been used for the treatment of gastrointestinal and colonic [78]. Ayurvedic literature shows that cinnamon has potent antiemetic, anti-diarrheal, anti-flatulent, and stimulant activities [79]. Cinnamon has a coagulant effect and thereforeit can be used against hemorrhaging [33]. Cinnamon increases the blood flow in the uterus and improves tissue regeneration [80]. Moreover, it possesses potent antibacterial, antifungal, antitermitic, larvicidal, nematicidal, and insecticidal properties [81,82,18,17,83]. More recently, scientific reports showed that cinnamon has potent neuroprotective, hepatoprotective, cardioprotective and gastroprotective effects due to its potent antioxidant and anti-inflammatory properties [84]. Cinnamon essential oil could be also used in aromatherapy, which is the therapeutic use of plant essential oils that can be absorbed into the body via the skin or the olfactory system. A recent research articled showed the benefits deriving from the use of cinnamon oil in massage for alleviating menstrual pain [85].

A search on the Clinical Trials Gov. database with the keyword "cinnamon" showed that there are 28 clinical trials, including 17 completed studies, six recruited studies, and one terminated study [86]. A search was conducted on the PubMed database using the keywords"antibacterial activity of cinnamon". The results returned 45 papers from 2010 up to 2015; the most interesting of these were summarized and critically discussed to provide a consistent review.The results showed that the antibacterial activity, expressed as inhibition zone, ranges from 7 to 18 mm for the application of 30 L, suggesting a high antibacterial activity [87,88]. The authors concluded that C. zeylanicum could be considered a valuable support in the treatment of infection and may contribute to the development of potential antimicrobial agents against MRSA bacteria [89].

The results showed that cinnamon extract is activeagainst both strains and, therefore, it represents an alternative source of natural antimicrobial substances for use in clinical practice for the treatment of cases of M. cattarhalis [90]. In 2012, Guerra et al. published an investigation on the antibacterial activity of the combination of C. zeylanicum essential oil and antibiotics, in which additive and synergistic effects were shown [91]. More recently, Yap et al. (2013) reached similar results. In fact, the authors showed that the combination of piperacillin and cinnamon bark essential oil induced a considerable reduction in the registered MIC values against a clinical strain of beta-lactamase-producing E. coli. The authors concluded that a reduced use of antibiotics could beemployed as a treatment strategy to decrease the adverse effects and possibly to reverse the beta-lactam antibiotic resistance [92].

TLC and GC-MS analysesof chemical composition revealed the presence of t-cinnamaldehyde (which was the most abundantsubstance, corresponding to 4.3%), eugenol (0.32%) and minor components such as cuminaldehyde, and -terpinene [79].

In 2014, Al-Mariri and Safi studied the antibacterial activity against Gram-negative bacteria (using a microdilution broth susceptibility assay) of cinnamon bark essential oil obtained via hydro-steam-distillation. The sample showed good antibacterial activity against the Gram-negative bacteria (E. coliO157:H7, Yersinia enterocolitica O9, Proteus spp. and Klebsiella pneumonia) with very low MIC values (12.5 L/mL, 6.25 L/mL, 1.5 L/mL and 3.125 L/mL, respectively) [93]. More recently, in 2015other research groups investigated the antibacterial activity of cinnamon essential oil and extracts andfound similar results [94,95]. Another investigation focusing on Gram-negative bacteria was published by Seukep et al. (2013) who studied the in vitro antibacterial activity of several Cameroonian dietary plants, including C. zeylanicum, against multidrug resistant (MDR) Gram-negative bacteria overexpressing active efflux pumps, which make bacteria resistant to antibiotic treatment. The authors concluded that the antibacterial activity of that cinnamon methanolic bark extract could be used in the treatment of infectious diseases induced by bacteria expressing MDR phenotypes [96].

Some studies showed that cinnamon extracts and essential oils could be active against oral cavity infections. Chaudhari et al. (2012) showed that cinnamon essential oil was active againstStreptococcus mutans and concluded that the use of cinnamon essential oils can be a good alternative to other antibacterial compounds against the bacteria responsible for oral infections.The results showed that the obtained inhibition zones vary with increasing concentration (5% to 20%) of cinnamon fresh leaf extract. Moreover, a complete inhibition of bacterial growth was registered after 12 h of contact, using NaOCl as a reference, which suggests that the cinnamon extract is active against both planktonic and biofilmforms; this was also observed in vivo [97]. L. acidophilus was less sensitive to this essential oil (1.46 L/mL). The authors concluded that promising in vitro data would require in vivo studies to determine the dose to be used in products for oral hygiene, which have no cytotoxicity [98].

The essential oil, whosemain constituents was cinnamaldehyde (97% w/w), showed antibacterial and bactericidal activity, with MIC values ranging from 250 to 1000 g/mL [99]. The authors showed the antibacterial activity, expressed as MIC and minimum lethal concentrations, of the essential oil obtained from C. verum [100]. In particular, cinnamon essential oil reduces the bacterial growth rate significantly in artificially contaminated samples when compared with an untreated control [101]. Similar investigations were performed a few years back by several research groups that studied the antibacterial activity of cinnamon against foodborne pathogens, especially in contaminated meat, such as Salmonella typhimurium, S. aureus and E. coli, Arcobacter butzeiri and Arcobacter skirrowii [102-104].The following paper is particularly noteworthy because the extract obtained from a cinnamon stick resulted to be active at room temperature (~23C) against L. monocytogenes, S. aureus, and Salmonella enterica in a food matrix different from meat and represented by cheese, suggesting that the extract is a potential natural food preservative [105].Based on these results, the authors concluded that cinnamon essential oil could be incorporated into food packaging materials or used to create an active modified atmosphere to reduce the contamination of Cronobacter species [106]. They suggested that these essential oils and their main active components could be used as natural alternatives for food preservation to retard or inhibit the bacterial growth of pathogenic and spoilage bacteria and to extend the shelf life of the food products [107].

Another practical application for the antibacterial activity of cinnamon essential oil was reported by Hill et al. (2013) who tested cinnamon bark extract entrapped in nanoparticles prepared with polyDL-lactide-co-glycolide (PLGA), a biocompatible polymer widely used in the pharmaceutical industry and which could be used in the food industry to deliver antimicrobial compounds to food matrices. Despite the above reported studies that promote the use of cinnamon applications in food and cosmetic products, the oral ingestion or skin applications of cinnamon or its components (i.e., cinnamaldehyde, eugenol, and cinnamic acid) is not always advisable and is recommended only in very small dosesCinnamon oil should be diluted to less than 2% before oral use (National Institutes of Health; U.S., 2015). This recommendation is related to the capacity ofcinnamaldehyde to deplete glutathione [108].

Cinnamon (Cinnamomum zeylanicum) bark essential oil (CBEO) has been used for thousands of years in Ayurvedic medicine to soothe aching joints and numb pain. It is still used for similar purposes in India, presumably because of its antiinflammatory property. CBEO typically contains a very high amount of cinnamaldehyde and a small amount of eugenol, among many other aromatic compounds. CBEO and cinnamaldehyde have been studied for their antibacterial antifungal anti-diabetic anti-inflammatory and anticancer activities, among others.Furthermore, CBEO has gained popularity for use in skin care products; however, research on its effects on human skin is largely scarce. A recent study conducted on human keratinocytes demonstrated the antioxidant effect of cinnamaldehyde, as well as its potential for treating skin disorders [109-116].

References

1. Gruenwald, J., Freder, J., & Armbruester, N. (2010). Cinnamon and health. Critical reviews in food science and nutrition, 50(9), 822-834..
2. Sangal, A. (2011). Role of cinnamon as beneficial antidiabetic food adjunct: A review. Advances in Applied Science Research, 2(4), 440-450.
3. Peng, X., Cheng, K. W., Ma, J., Chen, B., Ho, C. T., Lo, C., ... & Wang, M. (2008). Cinnamon bark proanthocyanidins as reactive carbonyl scavengers to prevent the formation of advanced glycation endproducts. Journal of agricultural and food chemistry, 56(6), 1907-1911.
4. Yeh, H. F., Luo, C. Y., Lin, C. Y., Cheng, S. S., Hsu, Y. R., & Chang, S. T. (2013). Methods for thermal stability enhancement of leaf essential oils and their main constituents from indigenous cinnamon (Cinnamomum osmophloeum). Journal

of agricultural and food chemistry, 61(26), 6293-6298.
5. Chang, C. W., Chang, W. L., Chang, S. T., & Cheng, S. S. (2008). Antibacterial activities of plant essential oils against Legionella pneumophila. Water research, 42(1-2), 278-286.
6. Marongiu, B., Piras, A., Porcedda, S., Tuveri, E., Sanjust, E., Meli, M., ... & Rescigno, A. (2007). Supercritical CO2 extract of Cinnamomum zeylanicum: chemical characterization and antityrosinase activity. Journal of agricultural and food chemistry, 55(24), 10022-10027.
7. Chou, S. T., Chang, W. L., Chang, C. T., Hsu, S. L., Lin, Y. C., & Shih, Y. (2013). Cinnamomum cassia essential oil inhibits α-MSH-induced melanin production and oxidative stress in murine B16 melanoma cells. International journal of molecular sciences, 14(9), 19186-19201.
8. National Institutes of Health (NIH). Herbs at a glance. Cinnamon https://w w w.cinnamonvogue.com/D OWNLOADS/ Cinnamon%20Side%20Effects.pdf. Accessed September 7, 2015.
9. Mccarthy K. The Benefits of Cinnamon Sticks 2015. http://www.livestrong.com/article/267542-the-benefits-of-cinnamon-sticks/. Published 2015.
10. Burns E. What to Do With Cinnamon Sticks? https://www.leaf.tv/articles/what-to-do-with-cinnamon-sticks/. Published 2016.
11. Minich S, Msom L. Chinese Herbal Medicine in Women's Health. Women's Health; 2008.
12. Wang, S. Y., Chen, P. F., & Chang, S. T. (2005). Antifungal activities of essential oils and their constituents from indigenous cinnamon (Cinnamomum osmophloeum) leaves against wood decay fungi. Bioresource technology, 96(7), 813-818.
13. Chang, S. T., Chen, P. F., & Chang, S. C. (2001). Antibacterial activity of leaf essential oils and their constituents from Cinnamomum osmophloeum. Journal of ethnopharmacology, 77(1), 123-127.
14. Mathew, S., & Abraham, T. E. (2006). In vitro antioxidant activity and scavenging effects of Cinnamomum verum leaf extract assayed by different methodologies. Food and Chemical Toxicology, 44(2), 198-206.
15. Tung, Y. T., Yen, P. L., Lin, C. Y., & Chang, S. T. (2010). Anti-inflammatory activities of essential oils and their constituents from different provenances of indigenous cinnamon (Cinnamomum osmophloeum) leaves. Pharmaceutical biology, 48(10), 1130-1136.
16. , S. S., Liu, J. Y., Huang, C. G., Hsui, Y. R., Chen, W. J., & Chang, S. T. (2009). Insecticidal activities of leaf essential oils from Cinnamomum osmophloeum against three mosquito Cheng species. Bioresource Technology, 100(1), 457-464.
17. Kong, J. O., Lee, S. M., Moon, Y. S., Lee, S. G., & Ahn, Y. J. (2007). Nematicidal activity of cassia and cinnamon oil compounds and related compounds toward Bursaphelenchus xylophilus (Nematoda: Parasitaphelenchidae). Journal of nematology, 39(1), 31.
18. Cheng, S. S., Liu, J. Y., Tsai, K. H., Chen, W. J., & Chang, S. T. (2004). Chemical composition and mosquito larvicidal activity of essential oils from leaves of different Cinnamomum osmophloeum provenances. Journal of agricultural and food chemistry, 52(14), 4395-4400.
19. Kwon, H. K., Hwang, J. S., So, J. S., Lee, C. G., Sahoo, A., Ryu, J. H., ... & Im, S. H. (2010). Cinnamon extract induces tumor cell death through inhibition of NFκB and AP1. BMC cancer, 10(1), 1-10.
20. Kearney, P. M., Whelton, M., Reynolds, K., Whelton, P. K., & He, J. (2004). Worldwide prevalence of hypertension: a systematic review. Journal of hypertension, 22(1), 11-19.
21. , M., Lopez, A. D., Rodgers, A., Vander Hoorn, S., Murray, C. J., & Comparative Risk Ezzati Assessment Collaborating Group. (2002). Selected major risk factors and global and regional burden of disease. the lancet, 360(9343), 1347-1360.
22. Whelton, P. K., He, J., Appel, L. J., Cutler, J. A., Havas, S., Kotchen, T. A., ... & National High Blood Pressure Education Program Coordinating Committee. (2002). Primary prevention of hypertension: clinical and public health advisory from The National High Blood Pressure Education Program. Jama, 288(15), 1882-1888.
23. Sacks, F. M., Svetkey, L. P., Vollmer, W. M., Appel, L. J., Bray, G. A., Harsha, D., ... & Cutler, J. A. (2001). Effects on blood pressure of reduced dietary sodium and the Dietary Approaches to Stop Hypertension (DASH) diet. New England journal of medicine, 344(1), 3-10.
24. Xue, Y. L., Shi, H. X., Murad, F., & Bian, K. (2011). Vasodilatory effects of cinnamaldehyde and its mechanism of action in the rat aorta. Vascular health and risk management, 7, 273.
25. El-Bassossy, H. M., Fahmy, A., & Badawy, D. (2011). Cinnamaldehyde protects from the hypertension associated with diabetes. Food and chemical toxicology, 49(11), 3007-3012.
26. Vijan, S., & Hayward, R. A. (2003). Treatment of hypertension in type 2 diabetes mellitus: blood pressure goals, choice of agents, and setting priorities in diabetes care. Annals of internal medicine, 138(7), 593-602.
27. Akilen, R., Tsiami, A., Devendra, D., & Robinson, N. (2010). Glycated haemoglobin and blood pressure-lowering effect of cinnamon in multi-ethnic Type 2 diabetic patients in the UK: a randomized, placebo-controlled, double-blind clinical trial. Diabetic medicine, 27(10), 1159-1167.
28. Talpur, N., Echard, B., Ingram, C., Bagchi, D., & Preuss, H. (2005). Effects of a novel formulation of essential oils on glucose–insulin metabolism in diabetic and hypertensive rats: a pilot study. Diabetes, Obesity and Metabolism, 7(2), 193-199.
29. Akilen, R., Pimlott, Z., Tsiami, A., & Robinson, N. (2013). Effect of short-term administration of cinnamon on blood pressure in patients with prediabetes and type 2 diabetes. Nutrition, 29(10), 1192-1196.
30. Gilani, A. H., Jabeen, Q., Khan, A. U., & Shah, A. J. (2007). Gut modulatory, blood pressure lowering, diuretic and sedative activities of cardamom. Journal of ethnopharmacology, 115(3), 463-472.
31. Lin, R. J., Lo, W. L., Wang, Y. D., & Chen, C. Y. (2008). A novel cytotoxic monoterpenoid from the leaves of Cinnamomum subavenium. Natural Product Research, 22(12), 1055-1059.

32. Shan, B., Cai, Y. Z., Sun, M., & Corke, H. (2005). Antioxidant capacity of 26 spice extracts and characterization of their phenolic constituents. Journal of agricultural and food chemistry, 53(20), 7749-7759.
33. Rao, P. V., & Gan, S. H. (2014). Cinnamon: a multifaceted medicinal plant. Evidence-Based Complementary and Alternative Medicine, 2014.
34. Block, W. (2017). Cinnamon Improves Oxygen Transport and Blood Pressure.. http://www.life-enhancement.com/magazine/article/2389-cinnamon-improves-oxygen-transport-and-blood-pressure. Published 2017
35. Qin, B., Panickar, K. S., & Anderson, R. A. (2010). Cinnamon: potential role in the prevention of insulin resistance, metabolic syndrome, and type 2 diabetes. Journal of diabetes science and technology, 4(3), 685-693.
36. Shen, Q., Chen, F., & Luo, J. (2002). Comparison studies on chemical constituents of essential oil from ramulus cinnamomi and cortex cinnamomi by GC-MS. Zhong yao cai= Zhongyaocai= Journal of Chinese Medicinal Materials, 25(4), 257-258.
37. Paranagama, P. A., Wimalasena, S., Jayatilake, G. S., Jayawardena, A. L., Senanayake, U. M., & Mubarak, A. M. (2010). A comparison of essential oil constituents of bark, leaf, root and fruit of cinnamon (Cinnamomum zeylanicum Blum) grown in Sri Lanka. Journal of the National Science Foundation of Sri Lanka, 29(3-4).
38. Chericoni, S., Prieto, J. M., Iacopini, P., Cioni, P., & Morelli, I. (2005). In vitro activity of the essential oil of Cinnamomum zeylanicum and eugenol in peroxynitrite-induced oxidative processes. Journal of agricultural and food chemistry, 53(12), 4762-4765.
39. Prakash, D., Suri, S., Upadhyay, G., & Singh, B. N. (2007). Total phenol, antioxidant and free radical scavenging activities of some medicinal plants. International journal of food sciences and nutrition, 58(1), 18-28.
40. Simić, A., Soković, M. D., Ristić, M., Grujić-Jovanović, S., Vukojević, J., & Marin, P. D. (2004). The chemical composition of some Lauraceae essential oils and their antifungal activities. Phytotherapy Research: An International Journal Devoted to Pharmacological and Toxicological Evaluation of Natural Product Derivatives, 18(9), 713-717.
41. Usta, J., Kreydiyyeh, S., Barnabe, P., Bou-Moughlabay, Y., & Nakkash-Chmaisse, H. (2003). Comparative study on the effect of cinnamon and clove extracts and their main components on different types of ATPases. Human & experimental toxicology, 22(7), 355-362.
42. für Risikobewertung, B. (2006). High daily intakes of cinnamon: health risk cannot be ruled out. BfR Health Assessment, 44.
43. Abraham, K., Wöhrlin, F., Lindtner, O., Heinemeyer, G., & Lampen, A. (2010). Toxicology and risk assessment of coumarin: focus on human data. Molecular nutrition & food research, 54(2), 228-239.
44. European Food Safety Authority (EFSA). (2008). Coumarin in flavourings and other food ingredients with flavouring properties-Scientific Opinion of the Panel on Food Additives, Flavourings, Processing Aids and Materials in Contact with Food (AFC). EFSA Journal, 6(10), 793.
45. Jayaprakasha, G. K., & Rao, L. J. M. (2011). Chemistry, biogenesis, and biological activities of Cinnamomum zeylanicum. Critical reviews in food science and nutrition, 51(6), 547-562.
46. Bandara, T., Uluwaduge, I., & Jansz, E. R. (2012). Bioactivity of cinnamon with special emphasis on diabetes mellitus: a review. International journal of food sciences and nutrition, 63(3), 380-386.
47. Wansi, S. L., Nyadjeu, P., Ngamga, D., Mbuyo, E. P. N., Nguelefack, T. B., & Kamanyi, A. (2007). Blood pressure lowering effect of the ethanol extract from the stembark of cinnamomum zeylanicum (lauraceae) in rats. Pharmacol online, 3, 166-176.
48. Jayaprakasha, G. K., Jagan Mohan Rao, L., & Sakariah, K. K. (2003). Volatile constituents from Cinnamomum zeylanicum fruit stalks and their antioxidant activities. Journal of agricultural and food chemistry, 51(15), 4344-4348.
49. Jayaprakasha, G. K., Negi, P. S., Jena, B. S., & Rao, L. J. M. (2007). Antioxidant and antimutagenic activities of Cinnamomum zeylanicum fruit extracts. Journal of food composition and analysis, 20(3-4), 330-336.
50. Ranjbar, A., Ghaseminejhad, S., Takalu, H., Baiaty, A., Rahimi, F., & Abdollahi, M. (2007). Anti oxidative stress potential of cinnamon (cinnamomum zeylanicum) in operating room personnel; a before/after cross sectional clinical trial. Int J Pharmacol, 3(6), 482-86.
51. Peterson, D. W., George, R. C., Scaramozzino, F., LaPointe, N. E., Anderson, R. A., Graves, D. J., & Lew, J. (2009). Cinnamon extract inhibits tau aggregation associated with Alzheimer's disease in vitro. Journal of Alzheimer's Disease, 17(3), 585-597.
52. Takasao, N., Tsuji-Naito, K., Ishikura, S., Tamura, A., & Akagawa, M. (2012). Cinnamon extract promotes type I collagen biosynthesis via activation of IGF-I signaling in human dermal fibroblasts. Journal of agricultural and food chemistry, 60(5), 1193-1200.
53. Tsuji-Naito, K. (2008). Aldehydic components of cinnamon bark extract suppresses RANKL-induced osteoclastogenesis through NFATc1 downregulation. Bioorganic & medicinal chemistry, 16(20), 9176-9183.
54. Rao, H. J. (2012). Lakshmi: Anti-diarrhoeal activity of the aqueous extract of the bark of cinnamomum zeylanicum linn in mice. J Clin Diagn Res, 6, 215-219.
55. Farahpour, M. R., & Habibi, M. (2012). Evaluation of the wound healing activity of an ethanolic extract of Ceylon cinnamon in mice. Vet Med, 57(1), 53-57.
56. Kamath, J. V., Rana, A. C., & Roy Chowdhury, A. (2003). Pro-healing effect of Cinnamomum zeylanicum bark. Phytotherapy Research: An International Journal Devoted to Pharmacological and Toxicological Evaluation of Natural Product Derivatives, 17(8), 970-972.
57. Eidi, A., Mortazavi, P., Bazargan, M., & Zaringhalam, J.

(2012). Hepatoprotective activity of cinnamon ethanolic extract against CCI4-induced liver injury in rats. Excli Journal, 11, 495.
58. Lu, J., Zhang, K., Nam, S., Anderson, R. A., Jove, R., & Wen, W. (2010). Novel angiogenesis inhibitory activity in cinnamon extract blocks VEGFR2 kinase and downstream signaling. Carcinogenesis, 31(3), 481-488.
59. Cao, H., Urban Jr, J. F., & Anderson, R. A. (2008). Cinnamon polyphenol extract affects immune responses by regulating anti-and proinflammatory and glucose transporter gene expression in mouse macrophages. The Journal of nutrition, 138(5), 833-840.
60. Krishnamoorthy, B.; Rema, J. End uses of cinnamon and cassia. In Cinnamon and Cassia: The Genus Cinnamomum; Ravindran, P.N., Babu, K.N., Eds.; CRC Press: Boca Raton, FL, USA, 2004.
61. Jakhetia, V., Patel, R., Khatri, P., Pahuja, N., Garg, S., Pandey, A., & Sharma, S. (2010). Cinnamon: a pharmacological review. Journal of advanced scientific research, 1(02), 19-23.
62. Khasnavis, S., & Pahan, K. (2012). Sodium benzoate, a metabolite of cinnamon and a food additive, upregulates neuroprotective Parkinson disease protein DJ-1 in astrocytes and neurons. Journal of neuroimmune pharmacology, 7(2), 424-435.
63. Kim, S. H., Hyun, S. H., & Choung, S. Y. (2006). Anti-diabetic effect of cinnamon extract on blood glucose in db/db mice. Journal of ethnopharmacology, 104(1-2), 119-123.
64. Brierley, S. M., & Kelber, O. (2011). Use of natural products in gastrointestinal therapies. Current Opinion in Pharmacology, 11(6), 604-611.
65. Jiffri, O., & Zahira, M. F. (2011). Urinary tract infection with Esherichia coli and antibacterial activity of some plants extracts.
66. Leung, E., Weil, D. E., Raviglione, M., & Nakatani, H. (2011). The WHO policy package to combat antimicrobial resistance. Bulletin of the World Health Organization, 89, 390-392.
67. Nabavi, S. M., Marchese, A., Izadi, M., Curti, V., Daglia, M., & Nabavi, S. F. (2015). Plants belonging to the genus Thymus as antibacterial agents: From farm to pharmacy. Food chemistry, 173, 339-347.
68. Högberg, L. D., Heddini, A., & Cars, O. (2010). The global need for effective antibiotics: challenges and recent advances. Trends in pharmacological sciences, 31(11), 509-515.
69. Barceloux, D. G. (2009). Cinnamon (cinnamomum species). Disease-a-month, 6(55), 327-335.
70. Madan, M. S., & Kannan, S. (2004). Economics and marketing of cinnamon and cassia–A global view. In Cinnamon and Cassia (pp. 301-326). CRC Press.
71. Ranatunga, J., Senanayake, U. M., & Wijesekera, R. O. B. (2004). Cinnamon and Cassia: The Genus Cinnamonum.
72. Muchuweti, M. (2007). Phenolic composition and antioxidant properties of some spices M. Muchuweti, E. Kativu, CH Mupure, C. Chidewe, AR Ndhlala and MAN Benhura Department of Biochemistry, University of Zimbabwe. Am. J. Food Technol, 2(5), 414-420.
73. Wong, Y. C., Ahmad-Mudzaqqir, M. Y., & Wan-Nurdiyana, W. A. (2014). Extraction of essential oil from cinnamon (Cinnamomum zeylanicum). Oriental journal of chemistry, 30(1), 37.
74. Jayaprakasha, G. K., Jagan Mohan Rao, L., & Sakariah, K. K. (2000). Chemical composition of the flower oil of Cinnamomum zeylanicum Blume. Journal of agricultural and food chemistry, 48(9), 4294-4295.
75. Filoche, S. K., Soma, K., & Sissons, C. H. (2005). Antimicrobial effects of essential oils in combination with chlorhexidine digluconate. Oral microbiology and immunology, 20(4), 221-225.
76. Chaudhary, S. S., Tariq, M., Zaman, R., & Imtiyaz, S. (2013). The In vitro anti-acne activity of two unani drugs. Ancient science of life, 33(1), 35.
77. Vijayan, K. K., & Thampuran, R. A. (2004). 11 Pharmacology and Toxicology of Cinnamon and Cassia. Cinnamon and Cassia, 259.
78. European Medicines Agency. Assessment Report on Cinnamomum verum J.S. Presl, cortex and corticis aetheroleum. EMA/HMPC/246773/2009.
79. Naveed, R., Hussain, I., Tawab, A., Tariq, M., Rahman, M., Hameed, S., ... & Iqbal, M. (2013). Antimicrobial activity of the bioactive components of essential oils from Pakistani spices against Salmonella and other multi-drug resistant bacteria. BMC complementary and alternative medicine, 13(1), 1-10.
80. Reichling, J., Schnitzler, P., Suschke, U., & Saller, R. (2009). Essential oils of aromatic plants with antibacterial, antifungal, antiviral, and cytotoxic properties–an overview. Complementary Medicine Research, 16(2), 79-90.
81. Chang, S. T., & Cheng, S. S. (2002). Antitermitic activity of leaf essential oils and components from Cinnamomum osmophleum. Journal of Agricultural and Food Chemistry, 50(6), 1389-1392.
82. Tung, Y. T., Chua, M. T., Wang, S. Y., & Chang, S. T. (2009). Anti-inflammation activities of essential oil and its constituents from indigenous cinnamon (Cinnamomum osmophloeum) twigs. Bioresource technology, 99(9), 3908-3913.
83. Moselhy, S. S., & Ali, H. K. (2009). Hepatoprotective effect of cinnamon extracts against carbon tetrachloride induced oxidative stress and liver injury in rats. Biological research, 42(1), 93-98.
84. Rafatullah, S., Alqasoumi, S., Al-Dosary, M., Al-Yahya, M., & Al-Mofleh, I. (2011). Gastroprotective effect of a popular spice cinnamon "Cinnamomum zeylanicum" in rats. European Journal of Pharmacology, (668), e42.
85. Hur, M. H., Lee, M. S., Seong, K. Y., & Lee, M. K. (2012). Aromatherapy massage on the abdomen for alleviating menstrual pain in high school girls: a preliminary controlled clinical study. Evidence-Based Complementary and Alternative Medicine, 2012.
86. U.S. National Institutes of Health, ClinicalTrials.gov. Available online: http://clinicaltrial.gov/ (accessed on 1 November 2014).
87. U.S. National Library of Medicine, PubMed database. Avail-

able online: http://www.ncbi.nlm.nih. gov/pubmed (accessed on 1 November 2014).
88. Keskin, D., & Toroglu, S. (2011). Studies on antimicrobial activities of solvent extracts of different spices. Journal of Environmental Biology, 32(2), 251-256.
89. Mandal, S., DebMandal, M., Saha, K., & Pal, N. K. (2011). In vitro antibacterial activity of three Indian spices against methicillin-resistant Staphylococcus aureus. Oman Medical Journal, 26(5), 319.
90. Rasheed, M. U., & Thajuddin, N. (2011). Effect of medicinal plants on Moraxella cattarhalis. Asian Pacific journal of tropical medicine, 4(2), 133-136.
91. Guerra, F. Q. S., Mendes, J. M., Sousa, J. P. D., Morais-Braga, M. F., Santos, B. H. C., Melo Coutinho, H. D., & Lima, E. D. O. (2012). Increasing antibiotic activity against a multidrug-resistant Acinetobacter spp by essential oils of Citrus limon and Cinnamomum zeylanicum. Natural product research, 26(23), 2235-2238.
92. Yap, P. S. X., Lim, S. H. E., Hu, C. P., & Yiap, B. C. (2013). Combination of essential oils and antibiotics reduce antibiotic resistance in plasmid-conferred multidrug resistant bacteria. Phytomedicine, 20(8-9), 710-713.
93. Al-Mariri, A., & Safi, M. (2014). In vitro antibacterial activity of several plant extracts and oils against some gram-negative bacteria. Iranian journal of medical sciences, 39(1), 36.
94. Bardají, D. K. R., Reis, E. B., Medeiros, T. C. T., Lucarini, R., Crotti, A. E. M., & Martins, C. H. G. (2015). Antibacterial activity of commercially available plant-derived essential oils against oral pathogenic bacteria. Natural product research, 30(10), 1178-1181.
95. Saleem, M., Bhatti, H. N., Jilani, M. I., & Hanif, M. A. (2015). Bioanalytical evaluation of Cinnamomum zeylanicum essential oil. Natural product research, 29(19), 1857-1859.
96. Seukep, J. A., Fankam, A. G., Djeussi, D. E., Voukeng, I. K., Tankeo, S. B., Noumdem, J. A., ... & Kuete, V. (2013). Antibacterial activities of the methanol extracts of seven Cameroonian dietary plants against bacteria expressing MDR phenotypes. Springerplus, 2(1), 1-8.
97. Gupta, A., Duhan, J., Tewari, S., Sangwan, P., Yadav, A., Singh, G., ... & Saini, H. (2013). Comparative evaluation of antimicrobial efficacy of S yzygium aromaticum, O cimum sanctum and C innamomum zeylanicum plant extracts against E nterococcus faecalis: a preliminary study. International endodontic journal, 46(8), 775-783.
98. Miller, A. B., Cates, R. G., Lawrence, M., Soria, J. A. F., Espinoza, L. V., Martinez, J. V., & Arbizú, D. A. (2015). The antibacterial and antifungal activity of essential oils extracted from Guatemalan medicinal plants. Pharmaceutical biology, 53(4), 548-554.
99. Sleha, R., Mosio, P., Vydrzalova, M., Jantovska, A., Bostikova, V., & Mazurova, J. (2011). In vitro antimicrobial activities of cinnamon bark oil, anethole, carvacrol, eugenol and guaiazulene against Mycoplasma hominis clinical isolates. Biomed Pap Med Fac Univ Palacky Olomouc Czech Repub, 158(2), 208-11.
100. Lindeman, Z., Waggoner, M., Batdorff, A., & Humphreys, T. L. (2014). Assessing the antibiotic potential of essential oils against Haemophilus ducreyi. BMC complementary and alternative medicine, 14(1), 1-4.
101. Dussault, D., Vu, K. D., & Lacroix, M. (2014). In vitro evaluation of antimicrobial activities of various commercial essential oils, oleoresin and pure compounds against food pathogens and application in ham. Meat Science, 96(1), 514-520.
102. Tayel, A. A., El-Tras, W. F., Moussa, S. H., & El-Sabbagh, S. M. (2012). Surface decontamination and quality enhancement in meat steaks using plant extracts as natural biopreservatives. Foodborne Pathogens and Disease, 9(8), 755-761.
103. Chen, C. H., Ravishankar, S., Marchello, J., & Friedman, M. (2013). Antimicrobial activity of plant compounds against Salmonella Typhimurium DT104 in ground pork and the influence of heat and storage on the antimicrobial activity. Journal of food protection, 76(7), 1264-1269.
104. Irkin, R., Abay, S., & Aydin, F. (2011). Inhibitory effects of some plant essential oils against Arcobacter butzleri and potential for rosemary oil as a natural food preservative. Journal of medicinal food, 14(3), 291-296.
105. Shan, B., Cai, Y. Z., Brooks, J. D., & Corke, H. (2011). Potential application of spice and herb extracts as natural preservatives in cheese. Journal of Medicinal Food, 14(3), 284-290.
106. Fraňková, A., Marounek, M., Mozrová, V., Weber, J., Klouček, P., & Lukešová, D. (2014). Antibacterial activities of plant-derived compounds and essential oils toward Cronobacter sakazakii and Cronobacter malonaticus. Foodborne pathogens and disease, 11(10), 795-797.
107. Mith, H., Dure, R., Delcenserie, V., Zhiri, A., Daube, G., & Clinquart, A. (2014). Antimicrobial activities of commercial essential oils and their components against food-borne pathogens and food spoilage bacteria. Food science & nutrition, 2(4), 403-416.
108. Price, S., & Price, L. (Eds.). (2017). Aromatherapy for health professionals E-book. Elsevier Health Sciences..
109. Bardají, D. K. R., Reis, E. B., Medeiros, T. C. T., Lucarini, R., Crotti, A. E. M., & Martins, C. H. G. (2016). Antibacterial activity of commercially available plant-derived essential oils against oral pathogenic bacteria. Natural product research, 30(10), 1178-1181.
110. Ranasinghe, L., Jayawardena, B., & Abeywickrama, K. (2002). Fungicidal activity of essential oils of Cinnamomum zeylanicum (L.) and Syzygium aromaticum (L.) Merr et LM Perry against crown rot and anthracnose pathogens isolated from banana. Letters in Applied Microbiology, 35(3), 208-211.
111. Anderson, R. A., Qin, B., Canini, F., Poulet, L., & Roussel, A. M. (2013). Cinnamon counteracts the negative effects of a high fat/high fructose diet on behavior, brain insulin signaling and Alzheimer-associated changes. PloS one, 8(12), e83243.
112. Sartorius, T., Peter, A., Schulz, N., Drescher, A., Bergheim, I., Machann, J., ... & Hennige, A. M. (2014). Cinnamon extract improves insulin sensitivity in the brain and lowers liver fat in mouse models of obesity. PloS one, 9(3), e92358.

113. Mendes, S. J., Sousa, F. I., Pereira, D. M., Ferro, T. A., Pereira, I. C., Silva, B. L., ... & Fernandes, E. S. (2016). Cinnamaldehyde modulates LPS-induced systemic inflammatory response syndrome through TRPA1-dependent and independent mechanisms. International immunopharmacology, 34, 60-70.
114. Chen, Y. F., Wang, Y. W., Huang, W. S., Lee, M. M., Wood, W. G., Leung, Y. M., & Tsai, H. Y. (2016). Trans-cinnamaldehyde, an essential oil in cinnamon powder, ameliorates cerebral ischemia-induced brain injury via inhibition of neuroinflammation through attenuation of iNOS, COX-2 expression and NFκ-B signaling pathway. Neuromolecular medicine, 18(3), 322-333.
115. Lu T, Sheng H, Wu J, Cheng Y, Zhu J, Chen Y. Cinnamon extract improves fasting blood glucose and glycosylated hemoglobin level in Chinese patients with type 2 diabetes. Nutr Res. 2012;32:408-12.
116. Lu, Z., Jia, Q., Wang, R., Wu, X., Wu, Y., Huang, C., & Li, Y. (2011). Hypoglycemic activities of A-and B-type procyanidin oligomer-rich extracts from different Cinnamon barks. Phytomedicine, 18(4), 298-302.
117. Saleh, A. (2012). Anti-secretagogue and antiulcer effects of'Cinnamon'Cinnamomum zeylanicum in rats. Journal of Pharmacognosy and Phytotherapy, 4(4), 53-61.
118. Barbosa-Morais, N. L., Dunning, M. J., Samarajiwa, S. A., Darot, J. F., Ritchie, M. E., Lynch, A. G., & Tavare, S. (2010). A re-annotation pipeline for Illumina BeadArrays: improving the interpretation of gene expression data. Nucleic acids research, 38(3), e17-e17.
119. Bergamini, G., Bell, K., Shimamura, S., Werner, T., Cansfield, A., Müller, K., ... & Neubauer, G. (2012). A selective inhibitor reveals PI3Kγ dependence of TH17 cell differentiation. Nature chemical biology, 8(6), 576-582.
120. Chaudhari, L. K., Jawale, B. A., Sharma, S., Sharma, H., Kumar, C. D., & Kulkarni, P. A. (2012). Antimicrobial activity of commercially available essential oils against Streptococcus mutans. J Contemp Dent Pract, 13(1), 71-74.
121. Domaracký, M., Rehák, P., Juhás, Š., & Koppel, J. (2007). Effects of selected plant essential oils on the growth and development of mouse preimplantation embryos in vivo. Physiological research, 56(1).
122. Hassan, S. A., Barthwal, R., Nair, M. S., & Haque, S. S. (2012). Aqueous bark extract of Cinnamomum zeylanicum: a potential therapeutic agent for streptozotocin-induced type 1 diabetes mellitus (T1DM) rats. Tropical Journal of Pharmaceutical Research, 11(3), 429-435.
123. Hill, L. E., Taylor, T. M., & Gomes, C. (2013). Antimicrobial efficacy of poly (DL-lactide-co-glycolide)(PLGA) nanoparticles with entrapped cinnamon bark extract against listeria monocytogenes and salmonella typhimurium. Journal of Food Science, 78(4), N626-N632.
124. Nazari, H., Mohammadi, A., Safaryeh, M., & Khaleghian, A. (2013). Effect of Cinnamon zeylanicum essence and distillate on the clotting time. Journal of Medicinal Plants Research, 7(19), 1339-1343.
125. Ijaz, J., Imran, F., Rahman, Z. U., Muhammad Zargham, K., Faqir, M., Bilal, A., ... & Andleeb, S. (2012). Lipid lowering effect of Cinnamomum zeylanicum in hyperlipidaemic albino rabbits.
126. Kim, Y. G., Lee, J. H., Kim, S. I., Baek, K. H., & Lee, J. (2015). Cinnamon bark oil and its components inhibit biofilm formation and toxin production. International journal of food microbiology, 195, 30-39.
127. Kitazuru, E. R., Moreira, A. V. B., Mancini-Filho, J., Delincee, H., & Villavicencio, A. L. C. H. (2004). Effects of irradiation on natural antioxidants of cinnamon (Cinnamomum zeylanicum N.). Radiation Physics and Chemistry, 71(1-2), 39-41.
128. Markey, O., McClean, C. M., Medlow, P., Davison, G. W., Trinick, T. R., Duly, E., & Shafat, A. (2011). Effect of cinnamon on gastric emptying, arterial stiffness, postprandial lipemia, glycemia, and appetite responses to high-fat breakfast. Cardiovascular diabetology, 10(1), 1-10.
129. Emilia Abraham, T., & Mathew, S. (2006). Studies on the antioxidant activities of cinnamon (Cinnamomum verum) bark extracts, through various in vitro models.
130. Nyadjeu, P., Dongmo, A., Nguelefack, T. B., & Kamanyi, A. (2011). Antihypertensive and vasorelaxant effects of Cinnamomum zeylanicum stem bark aqueous extract in rats. Journal of Complementary and Integrative Medicine, 8(1), 1-18.
131. Ranjbar, A., Ghasmeinezhad, S., Zamani, H., Malekirad, A. A., Baiaty, A., Mohammadirad, A., & Abdollahi, M. (2006). Antioxidative stress potential of Cinnamomum zeylanicum in humans: a comparative cross-sectional clinical study. Clinical Practice, 3(1), 113.
132. Ravindran, P. N., Shylaja, M., Babu, K. N., & Krishnamoorthy, B. (2003). Botany and crop improvement of cinnamon and cassia. In Cinnamon and cassia (pp. 30-95). CRC Press.
133. Shen, Q., Chen, F., & Luo, J. (2002). Comparison studies on chemical constituents of essential oil from ramulus cinnamomi and cortex cinnamomi by GC-MS. Zhong yao cai= Zhongyaocai= Journal of Chinese Medicinal Materials, 25(4), 257-258.
134. Singh, G., Maurya, S., DeLampasona, M. P., & Catalan, C. A. (2007). A comparison of chemical, antioxidant and antimicrobial studies of cinnamon leaf and bark volatile oils, oleoresins and their constituents. Food and chemical toxicology, 45(9), 1650-1661.
135. Singh, R., Koppikar, S. J., Paul, P., Gilda, S., Paradkar, A. R., & Kaul-Ghanekar, R. (2009). Comparative analysis of cytotoxic effect of aqueous cinnamon extract from Cinnamomum zeylanicum bark with commercial cinnamaldehyde on various cell lines. Pharmaceutical biology, 47(12), 1174-1179.
136. Wong, Y. C., Ahmad-Mudzaqqir, M. Y., & Wan-Nurdiyana, W. A. (2014). Extraction of essential oil from cinnamon (Cinnamomum zeylanicum). Oriental journal of chemistry, 30(1), 37.