Pharmaceutical applications and phytochemical profile of *Cinnamomum burmannii*

Bandar E. Al-Dhubiab

Department of Pharmaceutical Science, College of Clinical Pharmacy, King Faisal University, Kingdom of Saudi Arabia

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ABSTRACT

Extensive studies have been carried out in the last decade to assess the pharmaceutical potential and screen the phytochemical constituents of *Cinnamomum burmannii*. Databases such as PubMed (MEDLINE), Science Direct (Embase, Biobase, biosis), Scopus, Scifinder, Google Scholar, Google Patent, Cochrane database, and web of science were searched using a defined search strategy. This plant is a member of the genus *Cinnamomum* and is traditionally used as a spice. *Cinnamomum burmannii* have been demonstrated to exhibit analgesic, antibacterial, anti-diabetic, anti-fungal, antioxidant, antirheumatic, anti-thrombotic, and anti-tumor activities. The chemical constituents are mostly cinnamyl alcohol, coumarin, cinnamic acid, cinnamaldehyde, anthocynin, and essential oils together with constituents of sugar, protein, crude fats, pectin, and others. This review presents an overview of the current status and knowledge on the traditional usage, the pharmaceutical, biological activities, and phytochemical constituents reported for *C. burmannii*.

Key words: Antibacterial, antioxidant, *Cinnamomum burmanni*, essential oil, Lauraceae

INTRODUCTION

Cinnamomum burmannii is a shrub or a small tree, commonly known as Indonesian cassia, Batavia cassia, and Padang cassia, and is a member of the Lauraceae family. The plant is distributed in Southeast Asia and is cultivated in parts of Indonesia and Philippines, the plant possess oblong-elliptical, 4–14 cm long, glossy green, oppositely arranged leaves and an ovoid 1-cm long fruit. The dried bark of the plant is found in the market in the form of rolls and quills, which is used for cooking and flavoring.[1]

MATERIALS AND METHODS

Several databases were systematically searched for the literature, which were published on the pharmaceutical applications and phytochemical profile of *Cinnamomum burmannii* in December 2011. The databases included PubMed (MEDLINE), *Science Direct, Scopus, Scifinder, Google Scholar, Google Patent, Cochrane database, and web of science. The search strategy included terms such as Cinnamomum burmannii*, phytochemical, therapeutic, application, essential oil, and chemical composition.

Address for correspondence:
Dr. Bandar E. Al-Dhubiab, Department of Pharmaceutical Science, College of Clinical Pharmacy, King Faisal University, Kingdom of Saudi Arabia. E-mail: baldhubiab@kfu.edu.sa

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TRADITIONAL USES

The dried inner bark of the plant is used as flavoring agent in foods, beverages, chewing gums, etc. The distilled bark oil and the oleoresin of the bark of the plant are used in soap and perfume manufacturing. In Mexico, it is also used for brewing chocolate and flavoring confectionary and liquors. The powdered bark is used for the treatment of nausea, flatulent dyspepsia, coughs, chest complaints, diarrhea, gripe, and malaria. The oil of the plant is known to possess anti-bacterial, carminative, and anti-fungal properties. The plant also acts as a source of timber in Malaysia. The plant is also economically important because the other species of this genus are expensive.[1-6]

BIOLOGICAL ACTIVITIES

Antibacterial activity

The extract of *C. Burmannii* was examined for antibacterial activity, minimum inhibitory concentration, and minimum bactericidal concentration using five common food-borne pathogenic bacteria such as *Bacillus cereus*, *Listeria monocytogenes*, *Staphylococcus aureus*, *Escherichia coli*, and *Salmonella anatum*.

Additionally, scanning electron microscopy was used to observe the morphological changes of bacteria treated with the crude extract. The major constituents of the extract were identified by gas chromatography-Mass spectrum and Liquid chromatography-Mass spectrum, and (E)-cinnamaldehyde was found to be the most predominant volatile oil component, along with other polyphenols proanthocyanidins and (epi) catechins. The extract showed significant antibacterial activity, and both (E)-cinnamaldehyde and proanthocyanidins contributed significantly to the antibacterial activity.[7]

In another attempt, Shan *et al.* examined the extracts of 46 dietary spices and medicinal herbs including *C. burmannii* for antibacterial activities using agar well diffusion method. Five bacterial strains such as ***Bacillus cereus***, ***Listeria monocytogenes***, ***Staphylococcus aureus***, ***Escherichia coli***, and ***Salmonella****anatum* were employed. They also assessed the total phenolic contents in the extracts. Interestingly, most of the extracts showed high levels of phenolics and good antibacterial activity, the inhibitory effects observed were higher for the Gram positive bacteria as compared to the Gram negative bacteria. Among the strains, the highest activity observed was against *S. aureus* and the least activity was observed against ***E. coli***. Highly positive relationships (R^2 = 0.73–0.93) were observed between antibacterial activities and phenolic content of the tested extracts against each bacterium. On the basis of these results, the study suggested that the antibacterial activity of the tested extracts were closely associated with their phenolic constituents.[8]

Further, the effects of *C. burmannii*, *Origanum vulgare*, *Eugenia caryophylata*, *Punica granatum* and *Vitis Vinifera* on *Listeria monocytogenes, Staphylococcus aureus,* and *Salmonella enteric* in raw pork at ~20°C was assessed. The effect of these extracts on lipid oxidation in the meat and the pH, color parameters, and thiobarbituric acid-reactive substances values were also investigated. The authors observed that all the extracts of these natural herbs were found to be effective against the bacteria. Further, the color parameters of the extract-treated pork changed slightly and the extracts also increased the stability of raw pork against lipid oxidation.[9]

Anti-inflammatory, analgesic and anti-diabetic activity

Khatib *et al.* examined 20 different traditional Indonesian medicinal herbs including *C. Burmannii* for their anti-inflammatory activity using soybean lipoxygenase (SLO) and hyaluronidase (HAse). Among the extracts, *C. burmannii* indicates the highest anti-inflammatory activity. The ethyl acetate fraction derived from the methanol extract of the bark of *C. burmannii* showed the highest level of SLO inhibitory activity. The extract was subjected to preparative HPLC to yield two compounds namely coumarin and 2-hydroxy-cinnamaldehyde. Among these, 2-hydroxy-cinnamaldehyde exhibited good SLO inhibitory activity (IC_{50} = 60 μM). However, none of the compounds showed any significant HAse inhibitory activity.[10]

Wu and Chou reported a method for the preparation of an extract bearing anti-inflammatory and analgesic properties from a group of plants including *C. burmannii*. The plant materials are soaked in an organic solvent, heated, filtered, and concentrated under reduced pressure to yield an extract that possess anti-inflammatory and analgesic properties.[11]

In one attempt, Cao *et al.* examined the effects of aqueous extract of *C. burmannii* and HPLC-purified cinnamon polyphenols (CP) on the protein and mRNA levels of insulin receptor, glucose transporter 4 (GLUT4), and tristetraprolin (TTP/ZFP36) in mouse 3T3-L1 adipocytes. Immuno-blotting revealed that CP increased IRβ levels while both aqueous extract and CP increased GLUT4 and TTP levels in the adipocytes. Quantitative real-time PCR indicated that aqueous extract (100 μg/mL) rapidly increased TTP mRNA levels by nearly six-folds in the adipocytes. Indeed, aqueous extract at higher concentrations decreased IRβ protein and IR mRNA levels, and its effect on GLUT4 mRNA levels showed a biphasic pattern in the adipocytes. Thus, the study suggested that the plant possesses higher potential to enhance the levels of proteins involved in insulin signaling, glucose transport, and anti-inflammatory/anti-angiogenesis response.[12]

Preparation of herbal extracts from Lythraceae and Lauraceae family plants including *C. burmannii* was reported by Tjandrawinata *et al.* The extract was found to exhibit several activities and could be used as an insulin resistance reducer, syndrome X normalizer, pre-diabetes and type 2 diabetes treatments, particularly as activator in insulin signal pathway, as modulator in glucose transport system, as modulator in adiponectin secretion, and as suppressor in insulin resistance.[13]

Gene expression and immune response activity

Cao *et al.* tested the cinnamon polyphenol extract (CPE) for regulating the immune function involving genes encoding tristetraprolin (TTP), proinflammatory cytokines, and glucose transporter (GLUT) families and the effects of CPE were compared with those of insulin and lipopolysaccharide (LPS) in mouse RAW264.7 macrophages. It was observed that CPE increased the TTP mRNA and protein levels, i.e., CPE (100 mg/L, 0.5–4 h) enhanced the TTP by two-folds and tumor necrosis factor (TNF) mRNA by six-folds when compared to controls. However, the base level of TTP was six-folds higher than that of TNF. Further, LPS (0.1 mg/L, 4 h) also increased the granulocyte-macrophage colony-stimulating factor, cyclooxgenase-2, interleukin 6 mRNA, TTP and TNF, levels by 39–1868 fold. In addition, the authors also observed that the CPE and LPS enhanced GLUT1 expression (the major GLUT form in macrophages) by three- and two-folds of that of the controls, respectively. Moreover, CPE increased TTP expression more rapidly than those of pro-inflammatory cytokines and the net increases of TTP mRNA levels were larger than those of pro-inflammatory cytokines. This study concluded that CPE can affect immune responses by regulating anti- and pro-inflammatory and GLUT gene expression.[14]

Cinnamon extracts are known to improve impaired glucose

tolerance, a metabolic syndrome. Studies were carried out to assess the effects of aqueous extract of *C. burmannii* on gene expression in cultured mouse for the expression of genes coding for adipokines, glucose transporter (GLUT) family, and insulin-signaling components in mouse 3T3-L1 adipocytes, using quantitative PCR. The authors observed that the aqueous extract (100 μg/mL) of the plant increased GLUT1 mRNA levels by ~2, 4 and 7 folds compared to control after 2, 4, and 16 h of administration, respectively. Further, the extract also reduced the expression of further genes encoding insulin-signaling pathway proteins (GSK3B, IGF1R, IGF2R, and PIK3R1). Observations from this study signify that the *C. burmannii* extract can regulate the expression of multiple genes in adipocytes.[15]

Antioxidant activity

Methanolic extracts of 50 traditional Indonesian medicinal plants including *C. burmannii* were evaluated for their inhibitory effects on the nitric oxide production in lipo-polysaccharide stimulated RAW264.7 macrophages and for antioxidant activity through the evaluation of free radical scavenging effect and reducing power. Among these, the extracts of *C. burmannii* inhibited lipo-polysaccharide-induced nitric oxide release and showed antioxidant activity on RAW264.7 cell.[16]

Panickar *et al.* examined the protective effects of CPE, which is reported to bear anti-oxidant and insulin-potentiating effects on cell swelling and produce depolarization of the inner mitochondrial membrane potential ($\Delta\Psi_m$) in ischemic injury. The authors observed that CPE reduces oxygen-glucose deprivation-induced cell swelling and also influences the decline in the inner mitochondrial membrane potential ($\Delta\Psi_m$) in cultures. These protective effects observed may be due to the inhibition of mitochondrial permeability transition mPT.[17]

Huang *et al.* isolated a melanin-like pigment (0.34 g/100 g) from the berry of *C. burmannii* (CBM), which possess low solubility in water and most common organic solvents. However, it was found to be slightly soluble in DMSO while it is soluble in alkaline aqueous solution. The isolate was evaluated for its antioxidant and sun protection factor (SPF). It was observed that the antioxidant activity of CBM was superior to those of a well-known antioxidant, BHT. Further, it was also observed that the reducing power and the metal chelating activities of CBM was concentration dependent. The *in vitro* determination of melanin-bearing gel formulations indicated that the SPF value of every formulation increased with the amount of melanin, which suggested the presence of additional compounds with sunscreen activity in the melanin extract.[18]

From the fruit extract of *C. burmannii,* an anthocyanin was isolated using semi-preparative HPLC. The effects of temperature, light, and pH were examined for the radical scavenging activity of the anthocyanin. The IC_{50} of the anthocyanin was found to be 4.6 μg/mL, the antioxidant capacity found to reduce significantly after heating it at 100°C for 5 h or for 30 min at 130°C. The increase of pH did not have any effect on the DPPH radical scavenging activity, while the DPPH radical scavenging activity was reduced sharply by exposure to fluorescence radiation for 1 h, and the sunlight intensity also effected the DPPH radical scavenging activity of the anthocyanin.[19]

Anti-tumor and anti-thrombotic effects

A preparation possessing anti-tumor effects was prepared from *Humulus lupulus*, *Pimenta officinalis*, *Salvia officinalis*, *Syzygium aromatica*, *Piper nigrum,* and *Cinnamomum* plants including *C. burmani*, and *Myristica fragrans*, by pulverizing the plants and extracting them with water and organic solvent, followed by column chromatographic separations to isolate the active ingredient. The preparations possess inhibitory effects against *Epstein Barr* virus and nasopharyngeal carcinoma.[20] Hwang *et al.* prepared an extract from *Woodfordia floribunda*, *C. burmannii*, *Areca catechu*, *Cinnamomum sintok*, *Parameria laevigata*, and *Homalomena javanica* by pulverizing the plants and then extracting them with 75% or 100% methanol at room temperature for 48 h, followed by filtering, concentration, and freeze drying. The extract was found to exhibit anti-thrombotic effects.[21]

Dental treatment

A preparation comprising at least one plant extract from a group of plants including *C. burmannii* was prepared by solvent extraction or CO_2 supercritical extraction. The extract was found to inhibit dental plaque formation and periodontal disease.[22] Xu prepared a method using the extracts of certain plants including *C. burmannii* for producing a chewing gum and bubble gum capable of preventing and treating decayed tooth and periodontitis. The extracts were filtered and dried to powder form and were mixed with sweetening agent such as stevioside and xylitol, softening agent, antioxidant, gum base, and essence; and formulated into chewing gum or bubble gum exhibiting antibacterial effect and was found to be useful for preventing and treating dental caries and periodontitis.[23]

Other activities

The extracts of 24 herbs and spices including *C. burmannii* were tested for their inhibitory effects on fructose-mediated protein glycation. The extract of *C. burmannii* was among the post potent inhibitors of glycation.[24] Hamura *et al.* prepared a glycosylation inhibitor formulation from a plant selected from a group of plants including *C. burmannii.* The extract obtained is mixed with food additive and prophylactic; the product was found to possess glycosylation inhibiting effect.[25]

A topical plaster was formulated from a group of plant extracts including *C. burmannii*, which exhibited several therapeutic activities such as dampness removing, collateral flow activating, blood circulation promoting, repercussive, and analgesic effects. This applicator can be applied externally to treat traumatic injury, rheumatism, rheumatoid arthritis, and arthralgia as well.[26,27]

Medicated liquid formulation was prepared from a group of plants including *C. burmannii* by grinding the plant materials

to granules, mixing, and soaking in 35–75% ethanol solution for 15–20 days under sealed condition. The medicated liquor possess therapeutic effects on rheumatic arthralgia, pain and blood stasis due to traumatic injury, traumatic hemorrhage, sprain, pains in bones and muscles, rheumatic arthritis, and soft tissue contusion.[28-32]

PHYTOCHEMICAL INVESTIGATIONS

Both bark and leaves of *C. Burmanii* have been assessed for the phytochemical constituents. A method was reported for the extraction of a pectic substance from bark or leaves of *C. burmannii*; the pectic substance possessed of 10–20% galacturonic acid, 80–90% degree of esterification, and viscosity of 1000 cP. Pulverized *C. burmannii* bark (500 g) was soaked in 10 L of water and stirred for 3 h, homogenized, and centrifuged at 10,000 rpm for 5 min, and the supernatant (9 L) was added to 18 L of acetone while stirring to isolate a viscous substance (50 g), which was purified by dissolving and homogenizing followed by freeze-drying to obtain a pectic (20 g) substance.[33]

Archer reported the presence of cinnamyl alcohol, coumarin, and cinnamaldehyde in *Cinnamomum zeylanicum*, *C. cassia* bark, and *C. burmannii* bark by HPLC on a LiChrosorb RP-8 reversed-phase column and a Brownlee RP-8 guard column (mobile phase: H_2O-MeOH-acetonitrile-tetrahydrofuran, 60:12:20:8), with comparison with a standard. The quantities of coumarin and cinnamaldehyde were 0.042% and 0.054%, while the quantities of cinnamyl alcohol were undetectable.[34] Iida *et al.* reported a method for the production of an amylase inhibitors from some species *Cinnamomum* including *C. burmannii* by defatting the plant and extracting with ethanol to obtain the product.[35] The main constituents of *Cinnamomum zeylanicum*, *C. cassia,* and *C. burmannii* were analyzed by HPLC, and the main constituents were found to be different for each species.[36] Xu *et al.* prepared a method for the extraction of high-quality DNA from *Cinnamomum cassia*, *C. zeylanicum,* and *C. burmannii* by adding 2% β-mercaptoethanol and 5% polyvinylpyrrolidone to the solution of the extracts and treating it with 1.5 mol/L ammonium acetate and incubating it at 0°C; the supernatant was extracted with phenol:chloroform.[37]

He *et al.* assessed seven plants of the *Cinnamomum* species including *C. burmannii* for four chemical constituents; cinnamaldehyde, cinnamic acid, cinnamyl alcohol, and coumarin, using RP-HPLC, and established a fingerprint comprising of five markers. *C. burmannii* was found to contain lower quantities of cinnamaldehyde (<2.00 mg/g).[38] Yan *et al.* conducted a HPLC fingerprint analysis on Cortex cinnamomi, in which 30 samples, including *C. burmannii,* were examined and 17 chromatographic peaks were selected as characteristic peaks and their relative peak areas were calculated for quantitative expression of the HPLC fingerprints. Two principal components were extracted by principal component analysis, and the study suggested that on the basis of these components the samples could be clustered reasonably into different groups corresponding to different species, thus providing a reliable method for quality assessment of traditional Chinese medicines.[39]

Subehan and Shigetosh isolated 17 compounds from the methanol extract of *C. burmannii*, of which two compounds (cinnamic aldehyde cyclic syringyl glycerol 1,3-acetal (1) and 5′-hydroxy-5-hydroxymethyl-4′′,5′′-methylenedioxy-1,2,3,4-dibenzo-1,3,5-cycloheptatriene (2), were found to be new [Figure 1]. The isolated compounds were assessed for their pre-incubation time-dependent inhibition of CYP3A4 at different time intervals (0 and 20 min). It was observed that the compound 5′-hydroxy-5-hydroxymethyl-4′′, 5′′-methylenedioxy -1, 2, 3, 4-dibenzo- 1, 3, 5-cycloheptatriene indicated greater inhibitory activity (>50%) after 20-min pre-incubation.[40]

Zhang *et al.* reported a method for the extraction of anthocyanin from the fruit of *C. burmannii.* The fruit was extracted thrice with ethanol (70%), at a temperature of 40°C, a solid–liquid ratio (1:2), for 20 min which yielded 97.15% anthocyanin.[41] Wang *et al.* reported a method for the extraction of melanin from the peel of *C. burmannii* by treating it with a base solution, followed by filtering and drying the solution. The extract obtained is hydrolyzed using hydrochloric acid and then dissolved with a base solution and extracted with petroleum ether and chloroform. These extracts are acidified and separated and washed with water and dried to obtain the melanin extract. The melanin extract obtained possess high adhesiveness, high light resistance, high thermal stability, and good antioxidant capacity.[42]

Gan *et al.* reported a method for the extraction of oils from *C. burmannii* seeds by extracting the plant material twice (each extraction for 40 min) using petroleum ether at 50°C yielded higher amount of oil (64.2%). The oil obtained possessed glyceryl trilaurate (40%), which was never isolated from this species before.[43] In another attempt, the leaves of *C. burmannii* were extracted and analyzed for flavonoids, which indicated higher amount of flavonoids possessing antioxidant activity. Furthermore, the isolated flavonoids (quercetin, kaempferol, and quercetrin) were characterized and quantified using HPLC.[44]

Zhang *et al.* assessed the amount of water content, sugar, protein, crude fats, pectin, anthocyanins, and proanthocyanidins contents in *C. burmannii* fruits. The total water contents in fresh whole fruits, pulp, and stone were found to be 52.29%, 64.69%, and 30.99%, respectively, while the mass percentages of pulp and stone in fresh fruits were found to be 64.06% and 35.88%, respectively. Further, the constituents in the dried pulp

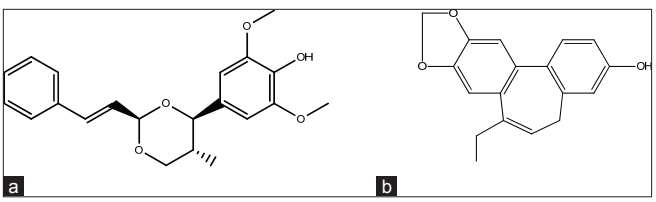

Figure 1: Structure of cinnamic aldehyde cyclic syringyl glycerol 1, 3-acetal (a) and 5′-hydroxy-5-hydroxymethyl-4′′,5′′-methylenedioxy-1,2,3,4-dibenzo-1,3,5-cycloheptatriene (b)

were found to be sugar (19.08%), protein (5.49%), crude fat (23.91%), pectin (1.16%), proanthocyanidins (1.27%), and 1.62% (anthocyanins). However, in the case of dried stone, the contents were found to be sugar (5.12%), protein (9.27%), crude fat (61.15%), pectin (10.46%), and procyanidins (3.47%).[45] Hence, it is likely that the amount of active constituents in the pulp and stone of fresh fruit varies.

Zhang *et al.* reported a method for the extraction of anthocyanin from *C. burmannii* fruit, by submerging the fruit in water and boiling it for 10–60 min, taking it out, and stirring it to separate the flesh and pit. The flesh is than soaked in a 60–95% alcoholic solution in a weight/volume ratio of 1:(1-5), the pH of the solution is maintained at 1–5, the temperature of the solution is maintained at 10–50°C for 15-60 min. The solution is than filtered and vacuum distilled at 30–60°C to reduce the alcohol in the solution to below 10%, the solution is than allowed to stand for 4–10 hours and then the supernatant is collected to obtain the anthocyanin extract. The anthocyanin extract applied to macroporous adsorption resin and eluted with 30–95% alcohol, and the elute is vacuum-dried at 60–90°C to obtain anthocyanin. The study suggested that the anthocyanin obtained by this method exhibit high stability, high anti-oxidative activity, high purity, and low raw material cost.[46]

Huang and Zhang developed a technique for the purification of crude anthocyanins from *C. burmannii* fruits. The extracts after defatting with petroleum ether were subjected to purification using different types of macroporous resins, such as DA201, DM301, DS401, D101 and DM-18. Static adsorption assays indicated that DM-18 had the highest adsorption capacity towards anthocyanins of up to 57.93 mg/g with 120 min equilibrium adsorption time and 88.47% of anthocyanins were desorbed with an 80% ethanol solution. The orthogonal array optimization indicated that the optimal conditions for desorption of anthocyanins from DM-18 were using 70% ethanol solution at a flow rate of 0.75 BV/h and pH 3.0.[47]

STUDIES ON ESSENTIAL OILS

It has been reported that the bark contains higher amount of essential oils, primarily 1,8-cineole, α-terpineol, camphor, terpinen-4-ol, borneol, α-pinene, β-caryophyllene, and p-cymene. Moreover, all these oils are present in the leaf as well. Rowaan investigated the presence of essential oil in the leaves of *C. burmannii*. They found that the leaves of *C. burmannii* possess essential oil (0.4%) and the major constituents were assumed to be cinnamaldehyde (45–62%) and eugenol (10%).[48] Li *et al.* investigated the leaves of *C. burmannii* extracted by steam distillation; the results showed the presence of d-borneol (70.81%) and 34 other different chemical constituents.[49] Ji *et al.* identified a total of 18 compounds from the essential oils from the leaf, bark, and branches of *C. burmannii* with the major constituents identified were 1,8-cineole, borneol, camphor, terpinen-4-ol, and α-terpineol.[50]

Chen *et al.* examined the essential oil of the leaves of *C. burmannii* obtained by steam distillation. The yield of the oil was between 0.54% and 0.85% and the safrole content of *C. burmannii* was found to be the highest among the other species of *Cinnamomum*.[51] Ding *et al.* examined the constituents of the leaf oils of ten Chinese Lauraceae species including *C. burmannii*. The identified 26–45 components, constituted 88.5–99.6% of the oils and the leaf oils were rich in monoterpenes (43.2–94.9%) and sesquiterpenes (1.3–47.4%).[52]

Lisawati and Sulianti investigated the effects of time interval of distillation and the mesh size of the bark powder of *C. burmannii* on the concentration of the major component cinnamylaldehyde. Different mesh sizes of bark powders were used (4, 8, and 20 mesh) and the distillate was collected after fixed intervals (1, 2, 3, and 4 h). The component was examined using GC and was found that the distillate obtained in the second hour yielded highest amount of volatile oil and cinnamylaldehyde. The relative percentages of the volatile oil contents in the first, second, third, and fourth hours were found to be 0.16%, 0.19%, 0.14%, and 0.08%, respectively. However, the cinnamylaldehyde content in the first, second, third, and fourth hours were found to be 24.88%, 29.36%, 23.29%, and 17.65%, respectively. Moreover, the highest volatile oil (0.22%) and cinnamylaldehyde (32.81%) contents were observed when the powder size of bark was 8 mesh. However, the volatile oil and cinnamylaldehyde contents for the mesh sizes 4 and 20 were found to be comparable. On the other hand, the yield obtained were found to be lower than the standard content of cinnamylaldehyde (60%), which may be due to the low quality of material, early harvesting time, and long time storage.[53]

Liu *et al.* examined the essential oils of the fruits, shoots, and leaves of *C. burmannii*in Yuebei by steam distillation. Forty-one constituents were characterized by GC-MS among which the major constituent was borneol (68.5%–73.8%). The other constituents identified were linalool, caryophyllene, nerolidol, elemene, citral, camphene, fenchol, guaiene, myrcene, sylvestrene, terpineol, and pinene.[54] Liu *et al.* examined the volatile oil of the stems and leaves of *C. burmannii* extracted by steam distillation. Forty-one constituents were analyzed using the GC-MS and the yield of the oils from the stems and leaves were found to be 96.78% and 99.72%, respectively.[55]

Thantsin *et al.* examined the semi-volatile constituents of the stem-bark of 10 *Cinnamomum* species including *C. burmannii*. The oils were extracted with diethyl ether and analyzed by GC-FID and GC-MS, which indicated the presence of 74 compounds. Cinnamaldehyde and α-cubebene were found to be the most common constituents among the group of plants examined.[56] Wang *et al.* examined the essential oils of *Cinnamomum cassia*, *Cinnamomum zeylanicum*, *Cinnamomum tamala*, *C. burmannii,* and *Cinnamomum pauciflorum* by hydro-distillation. Six compounds were identified from *C. burmannii* using GC/MS, while trans-cinnamaldehyde was found to be the major constituent of *C. burmannii* leaves.[57]

Yi *et al.* examined the volatile constituents of the leaves of *C. burmannii* extracted by solid-phase micro-extraction (SPME). Thirty-nine constituents accounting for 98.48% of the total volatile constituents were identified by GC-MS. The major constituents identified were borneol (19.68%), eucalyptol (10.49%), 1,7,7-trimethyl-bicyclo (2.2.1) hept-2-ylester (9.65%), alpha-pinene (7.36%), D-limonene (6.45%), and caryophyllene (5.80%).[58] Zhang *et al.* investigated the chemical constituents of the essential oil of Cortex Cinnamomi including *C. burmannii*, obtained from different pharmacies. A total of 45 compounds were identified by GC-MS and the yield of the samples were in the range 0.3–1.5 mL/g, the content of trans-cinnamaldehyde of the samples was found to be in the range of 17.1–73.9%.[59]

Essential oil of *C. burmannii* leaves analyzed by GC-MS indicated the presence of 40 volatile constituents accounting for 99.4% of total oil. The major constituents were found to be D-borneol (78.6%), bornyl acetate (3.26%), (-)-spathulenol (2.60%), and eucalyptol (1.92%), respectively.[60] In another attempt, Deng *et al.* investigated the chemical constituents and antioxidant activity of the essential oils of the leaves of *C. burmannii*. A total of 61 constituents were identified, which accounted for 93.58% of the oil. The maximal scavenging rate on DPPH and ABTS+ radical reached to 21.71% and 58.89%, respectively. The oils showed weak reductive capability as compared to BHT. The major constituents identified were caryophyllene (21.71%), eucalyptol (18.22%), guaiol (7.52%), (+)-α-terpineol (7.06%), *(-)*-β-pinene (3.57%), γ-eudesmol (3.33%), bulnesol (3.16%), (Z)-nerolidol (3.16%), elemol (2.67%), α-caryophyllene (2.22%), (1S)-β-pinene (1.9%), (-)-terpinen-4-ol (1.8%), (+)-ledene (1.35%), caryophyllene oxide (1.29%), and γ-terpinen (1.05%). The oil indicated good scavenging activities on ABTS+ radical and low activities on scavenging DPPH radical and reducing power, while the antioxidant activities of these oils were concentration dependent.[61]

CONCLUSION

C. burmanni, a traditional medicinal plant has long been used as a spice, food preservative, and food flavoring. The pharmacological studies have shown anti-bacterial, anti-fungal, antioxidant, anti-thrombotic, anti-inflammatory, anti-tumor, dental plaque formation and periodontal disease inhibitory, glycosylation inhibitory, and radical scavenging activities. *C. burmanni* also possess therapeutic effects on rheumatic arthralgia, pain and blood stasis due to traumatic injury, traumatic hemorrhage, sprain, pains in bones and muscles, rheumatic arthritis, soft tissue contusion, collateral flow activating, blood circulation promoting, and repercussive effects. A wide range of biological activities have been reported for *C. burmanni*, but there is a great need for phytochemical investigations on the plant for development of an effective natural remedy and for the investigation of biologically active compounds responsible for the wide range of activities reported for the plant.

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