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Review article

COMPREHENSIVE REVIEW ON CARDAMOM (ELETTARIA CARDAMOMUM): PHARMACOGNOSTICAL DESCRIPTION, PHYTOCHEMISTRY AND ANALYTICAL APPROACHES

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Abstract

This article provides an in-depth analysis of Cardamom (*Elettaria cardamomum*), known as the "Queen of Spices," is a highly valued spice with significant culinary, medicinal, and industrial applications. Cardamom is widely cultivated in tropical regions, such as in India, Sri Lanka, and Guatemala, belonging to the *Zingiberaceae* family. This review highlights the botanical characteristics, phytochemical composition, and therapeutic potential of cardamom. Emphasis is given to its traditional and modern uses in health, culinary, and pharmaceutical domains. It is rich in essential oils, flavonoids, and other bioactive compounds that exhibit antioxidant, antimicrobial, anti-inflammatory, and digestive health-promoting properties. Furthermore, cardamom has demonstrated potential in managing metabolic disorders, cardiovascular health, and certain types of cancer in preclinical studies. The article also discusses cultivation practices, post-harvest processing. Despite its diverse benefits, challenges such as adulteration, sustainability in production, and the need for more clinical research remain. This review aims to provide comprehensive insights into cardamom's Pharmacognostical Description, Phytochemistry and Analytical Approaches.

Keywords: Cardamom, Pharmacognostical, Phytoconstituents, Botanical description

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Introduction

1.0 Introduction of Cardamom:

Cardamom, known as the "Queen of Spices," is a highly valued spice with significant importance in culinary, traditional, and medicinal practices. It is prized for its unique aroma and flavour, making it a staple in both sweet and savory dishes, teas, and desserts. In traditional medicine systems such as Ayurveda and Unani, cardamom has been used to treat GI problems, respiratory conditions, infections. Its essential oils and bioactive compounds are recognized for their therapeutic effects, including antioxidant, antimicrobial, and anti-inflammatory properties.

Historically, cardamom has been mentioned in ancient texts as a luxury commodity traded along spice routes connecting India to the Middle East and Europe. Cardamom is cultivated in tropical regions, India, Guatemala, are being the largest producers[1].

1.1 Identification, Authentication and source of cardamom:

A major plantation crop in India is cardamom, is belonging to the family "*Zingiberaceae"*. The seeds have a distinct warm, slightly spicy flavour and a lovely scent. The "queen of spices" has several therapeutic uses. Cardamom seeds are aromatic and help with bronchitis, piles, asthma, scabies, headaches, earaches, toothaches, kidneys, liver, uterus, rectum, and throat problems. They also reduce inflammation and induce thirst. The seeds are taken with honey or whey as a diuretic. Although cardamom seeds can help with flatulence, they are typically used in conjunction with other treatments. They are also used as a flavouring in other medications and as a spice in cookery. Amomum subalantum, the cardamom of Nepal, is thought to be beneficial as a liver and heart tonic. The seed's decoction for gargling helps with gum and tooth problems. It also relieves stomachaches and is an aromatic stimulant. Cardamom infusions and the Lesser Cardamom (*Eletaria cardamomum*) Moten are beneficial medicinal herbs[2]. During the infectious stage of influenza, ground cardamom seeds along with ginger, cloves, and caraway can aid with stomach issues, sore throats, and hoarseness. As a result, it is accurate to say that consuming a cardamom once daily with a tablespoonful of honey enhances vision, fortifies nerves, and promotes overall health. The term "a poor man's rich spice" refers to cardamom. In the spice industry, cardamoms come in two varieties: One is Eletteria with true cardamom (or tiny cardamom) and second is the genus Amomum includes the large cardamom, Nepal cardamom, and black cardamom.

Its seed pods flavour strongly of camphor and have a smokey quality that comes from the drying process. Cardamom is very expensive and after saffron and vanilla, cardamom is 3rd ranked in cost wise in the world. Its high cost is a reflection of its excellent reputation as a delightfully fragrant spice[3].

1.2 Taxonomical classification:

Kingdom	Plantae
Subkingdom	Tracheobionta
Division	Magnoliophyta
Superdivision	Spermatophyta
Class	Liliopsida
Subclass	Zingiberadae
Order	Zingiberales
Family	Zingiberaceae
Genus	Elestaria maton
Species	Elettaria cardamomum (L.) Maton

1.3. Origin and Geographical Distribution:

A 2000 BC clay tablet from the ancient Sumerian Nippur city, has the oldest known mention of cardamom (Weiss, 2002). In the fourth century BC, cardamom was traded between Greece and India. Although it is still up for question whether they were the same cardamoms or merely the ones that are now known as the large and little cardamoms, inferior grades were referred to as cardamom and better ones as kardamom. Prior to the mid-19th century, cardamom was a naturally occurring forest product. It wasn't until the demand for cardamom grew globally that it began to be grown on a huge scale through planned cultivation[4].

1.4. Plant Description:

The cardamom is an herbaceous perennial plant with 2-4 meters height. It has underground rhizomes that branch and produce a clump of green branches. The first year of a leafy shoot's existence is mostly devoted to vegetative growth and second year is devoted for the reproductive growth and the third year is a stage of ageing and death. In the first and second years, the base of the old shoots forms new buds, forming a cluster of old shoots. The quantity of young shoots and buds varies. Depending on the variety of the spice flowers are produced on upright flexuous inflorescences[5]. The lamina tapers into a pointed tip, and the leaves are lanceolate in shape, measuring 25 to 90 cm in length and 5 to 15 cm in breadth. The upper surface of the leaves is glossy and dark green, while the below surface is pale green. Depending on the cultivar, the leaf's lower surface may be pubescent (hairy) or smooth or glabrous. Therefore, the dark green leaves are grouped in two rows with a lengthy sheath, an undivided lanceolate leaf blade, and a generally stalkless appearance. The 45–120 cm long inflorescence emerges from the base of the leafy branches. An inflorescence is a spike that resembles a panicle and may have many or few blooms. Each flower has a bract positioned laterally and is in the aril of a subtending leaf. Racemes of hermaphrodite, zygomorphic flowers that are roughly 4 cm long and 1.5 cm broad are produced[6].

The beginning of the rainy season coincides with the flowering season (March to April in India). It takes 25 to 35 days to full bloom and 110 to 140 days to maturity. It is an ovate-globose capsule that ranges in hue from dark green to pale green. The genus Amomum differs from Elettaria in that it produces thickly-flowered, short-stalked or sensile blooms, as well as dense or loose clusters of fruits with thick flesh that dries to form a leathery fruit covering. Fruits are dehiscent, have three chambers, and are packed with seeds[7]. The capsule turns yellow when it ripens and contains 15–30 dark brown, aromatic, angled seeds that are about 3 mm long and have a thin mucilaginous aril. The seed is surrounded by a very thin membranous arillus that is made up of multiple layers of collapsed cells, is yellow in color, and contains oil[8].

A tiny canal that runs through the operculum is called the micropyle. A well-developed perisperm, contains parenchymatous cells contains starch grains and tiny prismatic calcium oxalate crystal in the center of each cell, is found within the testa. The endosperm and embryo, which are made of thin walled, protein containing cells which are surrounded by the perisperm. The spiral veins and pitted fibers of the fibrovascular bundles, empty parenchymatous cells, are characteristics that identify cardamom pericarps or husks when they are powdered[9].

1.5. Breeding:

Elettaria's somatic chromosome number is 2n = 48 or 52, but its basic chromosome number is x = 12. Cardamom is cross-pollinated, and the offspring of seedlings vary greatly.

1.6. Microscopy of Cardamom Seed:

There is a very thin membraneous arillus, enveloping the seed and composed of several layers of collapsed

Figure 1: T.S. (schematic) of Cardamom seed

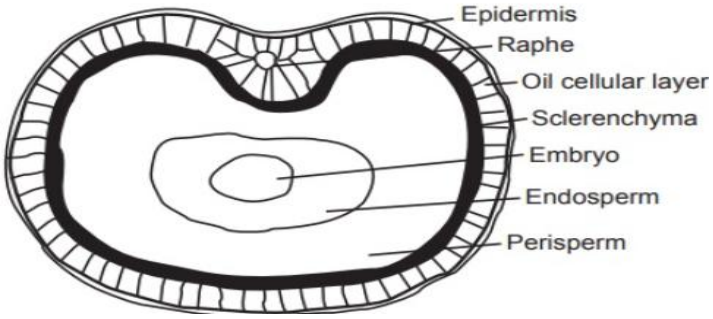
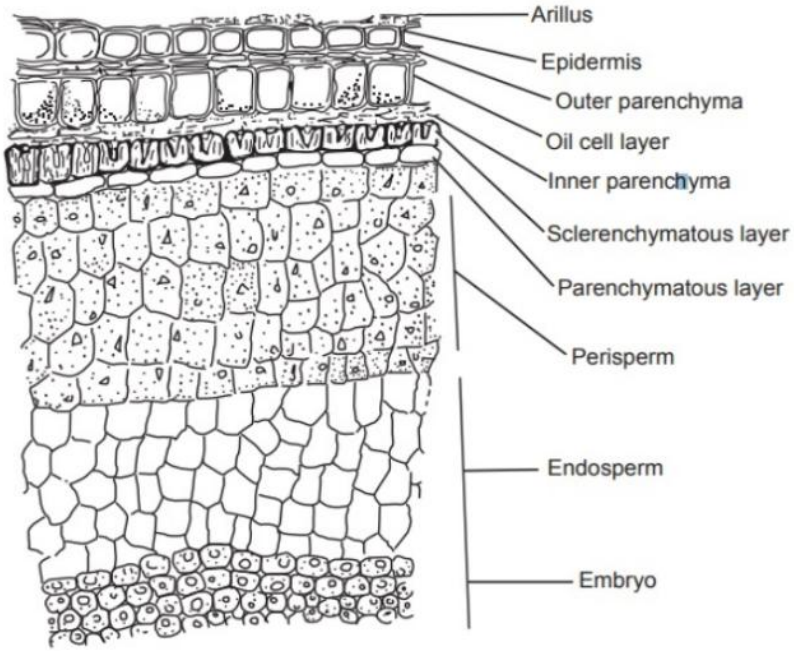


Figure 2: Transverse section of Cardamom seed



cells, yellow in colour, and containing oil. The brownish Testa enclosed in colourless flattened or collapsed parenchyma called as membranous arillus. Epidermis is made up of single layer thick walled, narrow and elongated. Outer parenchyma is consisting of 1-2 layer of collapsed parenchyma. Single layer of oil cell becoming 2-3 layers near rephae. Parenchymatous cells containing volatile oil are large, rectangular and thin walled. Inner parenchyma with 2-3 layers with thick-walled cell. Single layer of sclerenchymatous is dark brown with narrow lumen. Single layer of parenchymatous flattened cells.

Perisperm with thin walled, parenchymatous cells with starch grains and single prism of calcium oxalate crystal. Endosperm with thin-walled colourless parenchymatous cells containing protein as granular mass. Her starch is absent. Embryo are like endosperm with oil globules and aleurone grains[10].

2.0. Chemistry of Cardamom:

2.1. Phytochemical Study:

Volatile oil is the major component of cardamom. About 2.8 to 6.2% volatile oil, 1 to 10% fixed oil, 10% protein, 50% starch are all found in cardamom. Steam-volatile oil, fixed (fatty) oil, proteins, cellulose, pentosans, sugars, starches, silica, calcium oxalate, colors, and minerals are all present in dried cardamom fruit. Up to 50% of the seed is made up of starch, whereas up to 31% of the fruit husk is made up of crude fiber. For the two varieties of cardamom (Malabar and Mysore) cultivated in India, the volatile oil content of the seed's ranges from 6.5 to 10.5%. The volatile oil content of immature capsules, which are obtained in tiny numbers in all harvests (but especially in the most recent harvest), is low, ranging from 4 to 5% [11]. Cardamom's aroma and flavour are derived from its essential oils mainly contains α-terpinyl acetate (20–55%) and 1,8-cineole (20–60%), which give the plant its distinct flavour[12,13]. Among the minor components found in cardamom essential oil are borneol, 1,4-cineole, camphene, myrcene, limonene, etc. The amount and makeup of volatile oil, which controls the flavour and odour, is the primary determinant of cardamom quality[14]. Although it can reach 8%, the amount of volatile oil in the seeds is highly dependent on storage circumstances. The oil is mostly composed of oxygenated molecules, all of which have the potential to be fragrance compounds, and contains very few mono or hydrocarbons[15,16]. Cardamom (*E.cardamomum* Maton var. Minisula Barhill) volatile oil has a high concentration of 1,8 cineole, α cineole, and α terpinyl acetate and a low concentration of hydrocarbons[17-19]. The amount and makeup of volatile oil, which controls the flavour and odour, is the primary determinant of cardamom quality[20].

2.2. Analytical study:

Cardamom seeds' distinctive scent and therapeutic qualities are attributed to their flavonoids, phenolic chemicals, and essential oils (4.5–9.5%). α-terpinyl acetate (29.9–61.3%), 1,8-cineole (15.2–49.4%), and sabinene (1.9–4.9%) are the primary volatile components[21]. Its therapeutic effect is increased by the potent antioxidant qualities of phenolic acids and flavonoids like kaempferol and quercetin[22]. These bioactive substances have been identified and quantified using a variety of analytical methods, including UV spectroscopy and HPLC (High-Performance Liquid Chromatography)[23].

2.3 Analytical Review of *Elettaria Cardamomum*

2.3.1 Chemical Composition

The essential oil (EO) derived from Elettaria cardamomum, commonly known as cardamom, exhibits a complex chemical profile characterized by various volatile compounds. The composition of cardamom EO can vary significantly based on factors such as geographical origin, storage conditions, and distillation methods employed. Notably, studies have demonstrated that the essential oil content in cardamom seeds can reach up to 8%, with the principal constituents typically being α-terpineol, myrcene, limonene, and 1,8-cineol, among others[24-25].

The primary compounds found in cardamom EO include: α-terpineol (45%), Myrcene (27%), Limonene (8%), Menthone (6%), and 1,8-Cineol (2%). Other constituents reported in various studies include β-phellandrene, sabinene, and heptane, which contribute to the oil's sensory profile and biological activity.

2.3.2 Phytochemical Profile

Cardamom pods contain essential oils (2–8%), volatile constituents, flavonoids, terpenoids, phenolic acids, and sterols. Key volatile components include 1,8-cineole, α-terpineol, sabinene, and linalool, which are responsible for its distinctive aroma and pharmacological effects[26,27].

2.4 Advanced Analytical Techniques

2.4.1. Gas Chromatography (GC) and Gas Chromatography-Mass Spectrometry (GC-MS)

GC and GC-MS are the most widely used techniques for profiling the volatile oil components of cardamom. Identification and quantification of monoterpenes and sesquiterpenes such as 1,8-cineole, α-terpinyl acetate, and linalool. GC-MS enables structural elucidation and fingerprinting of complex volatile oil mixtures[28]. Verma et al. used GC-MS to identify more than 20 components in cardamom essential oil[29-31].

2.4.2. High-Performance Liquid Chromatography (HPLC)

HPLC is applied to quantify non-volatile polar compounds like flavonoids, phenolic acids, and alkaloids. Used for evaluating antioxidant flavonoids such as quercetin, rutin, catechins[32]. Offers high resolution and reproducibility in the analysis of bioactive markers.

2.4.3. Liquid Chromatography-Mass Spectrometry (LC-MS/MS)
LC-MS enables the detection of minor bioactive components that might be undetectable by conventional HPLC.
Identification of polyphenols, glycosides, and minor terpenoids. Provides both qualitative and quantitative analysis with high sensitivity, especially useful in metabolomic studies[33-35].

2.4.4. High-Performance Thin-Layer Chromatography (HPTLC)
HPTLC is a reliable technique for authentication and fingerprint profiling of herbal drugs. Detection and quantification of flavonoids, saponins, and volatile oil markers using derivatization reagents[36]. Use in standardization: Helps distinguish E. cardamomum from adulterants like Amomum subulatum.

2.4.5. Fourier-Transform Infrared Spectroscopy (FTIR)
FTIR spectroscopy is used to identify functional groups present in cardamom extracts. Peaks corresponding to –OH, –CH, C=O, and aromatic rings indicate the presence of flavonoids, terpenes, and phenolics[37]. Acts as a quick and non-destructive method for preliminary phytochemical screening.

2.4.6. UV-Vis Spectrophotometry
Utilized to estimate total phenolic content (TPC) and total flavonoid content (TFC). Assays used: Folin–Ciocalteu for TPC and aluminum chloride colorimetric method for TFC[38].

Conclusion:

The phytochemical components and ethnopharmacological characteristics of *E. cardamomum* that have been identified have been reviewed. To explore phytochemical constituent further phytochemical and advanced analytical techniques will be the need of a time.

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