Chapter 4
Plant Morphological Traits of *Elettaria cardamomum*

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4.1 Introduction

Spices are extensively used for flavor, color, aroma and preservation and are obtained from different parts of the plants: bark, buds, flowers, fruits, leaves, stems, roots, seeds, and stigmas. The term spice is distinguished from the term herb in that the latter is usually derived from the leaves of a plant and used in cooking, but any other part of the plant, often dried, is called a spice. Some examples are cloves buds; cinnamon-dried bark; ginger roots; peppercorns berries, cumin aromatic seed; saffron flower's stigma and cardamom pods of a perennial plant (Rajathi et al., 2017). Cardamom is one of the most expensive spices prepared from the seeds of different plants classified in the genus *Elettaria*. The capsules of small *Elettaria cardamomum* commonly encountered in commercial markets are shown as a zigzag heap (Fig. 4.1).

Apart from being a famous flavoring agent on the food tables of the world, it claims many applications as a medicine to cure some diseases. Cardamom, for example, may help lower blood pressure due to its antioxidant and diuretic traits by promoting urination that removes extra water from the living body, e.g., around the heart or in other body organs and tissues. Cardamom powder could increase the activity of certain enzymes that help in fighting cancer. The spice may also enhance the ability of natural killer cells to attack tumors. Cardamom tea has been observed to cause a slimming effect on the human body without any harmful effects. The

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Fig. 4.1 Capsules of small *Elettaria cardamomum*

major constituents of its essential oil are 1,8-cineole, α-terpinyl acetate, sabinene, and β-linalool. As narrated above, these could be used in food, aroma, and pharmaceutical applications (Ashokkumar et al., 2019, 2020, 2022). Due to its extensive uses highlighted above, it is called "*The Queen of Spices*" in India. Intensive research is currently underway to extend the spectrum of its applications.

4.2 Nomenclature and Classification

Cardamom, sometimes called cardamom or cardamom (Wikipedia, Encyclopedia Britannica), is a spice made from the seeds of several plants in the genera *Elettaria* and *Amomum* in the family Zingiberaceae. Both genera are native to the Indian Subcontinent and Indonesia (Wikipedia). Their small seed pods recognize them: triangular cross-sect and spindle-shaped, with a thin, paper-like outer shell and small, black seeds. *Elettaria* pods are light green and smaller, while *Amomum* pods are larger and dark brown.

The binomial nomenclature and botanical classification of cardamom are:

Kingdom	Unranked (Angiosperms) Plantae
Family	Zingiberaceae
Genus:	*Elettaria* and *Amomum*
Species:	*Elettaria cardamomum*/*cardamom*

4.3 Occurrence

Elettaria genus naturally occurs in India, Nepal, Bhutan, Pakistan, Nepal and Indonesia (Dictionary. Com). According to a Review by Rajathi et al. (2017), cardamom originated from the coastal area of India. It is grown in Guatemala, Tanzania, Sri Lanka, El Salvador, Vietnam, Laos and Cambodia. India is the leading exporter of dried cardamom. Cardamom is known as the "*Queen of Spices*" that grows from a thick rootstalk up to around 6–10 feet in height and is indigenously grown in the evergreen forests of the Western Ghats in South India. Different types of *Elettaria* are encountered that are distinguished based on the size and color of their pods. Based on the size of the pod, it is called small cardamom (Choti Elachi in India and Pakistan), while a similar species *Amomum* is called big cardamom (Moti Elachi) based on pod size. Based on the color of the pod former is called green cardamom, while the latter is called dark brown cardamom (KPT International Online).

Both species used for cardamom are native throughout tropical and subtropical Asia. The oldest references to cardamom are found in Sumer and the Ayurvedic literature of India (Baser, 2002). *Elettaria cardamomum* has gained the status of an export commodity and earner of foreign exchange due to its outstanding quality. According to a report from Export Development Board (EDB) Sri Lanka, due to the unique flavor of green cardamom cultivated in Sri Lanka, the green cardamom produced in Sri Lanka is known as Ceylon Cardamom that is available in the export market in the form of whole pods, powder and essential oil. The country meets about 0.1% of the global demand for cardamom, which amounts to 4000–5000 tons annually. Australia, Canada and Estonia, and India, major producers and exporters, are the primary buyers of Ceylon Cardamom, available in two grades. It is mainly cultivated in Kandy, Matale, Kegalle, Nuwara Eliya, Ratnapura and a part of Galle. Three types of cardamom are found in Sri Lanka and categorized based on the inflorescence shape as Malabar, Mysore and Vazhukka.

Cardamom consumption has drastically increased throughout the world during the last two decades. However, cardamom is mainly consumed in Middle Eastern countries, India, Pakistan, European countries, the USA, and Japan. Middle Eastern countries, such as Saudi Arabia and the United Arab Emirates, and South-East Asian countries, such as India, account for over 60% of global consumption.

4.4 General Structure and Morphology of Plant, Roots, Stem, Branches, Leaves and Seeds

4.4.1 General Structure of Plant

The general structure of the plant and the composition of its different parts are described below. The morphological structure of *E. cardamom* is exhibited in Fig. 4.2, while that of cardamom in Fig. 4.3.

Fig. 4.2 *Elettaria cardamomum* plants

Fig. 4.3 *Elettaria cardamomum* capsules

The leafy off-shoots of the cardamom plant grow up to 1.5–6 m (5–20 feet) from the roots and are equipped with the tendency to branch. The flowering off-shoots are approximately 1 m/3 feet long and may be upright or sprawling in different directions. Every shoot bears many flowers about 5 cm/2 inches in diameter, with greenish petals and a purple-veined white lip. The whole fruit is 0.8–1.5 cm long and is a green three-sided oval capsule containing 15–20 dark, reddish brown to brownish black, hard, angular seeds. The essential oil of cardamom occurs in large parenchymal cells under the epidermis of the seed coat. The essential oil content of the seed is from 2% to 10%. Cineole and α-terpinyl acetate are principal components (Encyclopedia Britannica, Baser, 2002).

According to another report from India, cardamom is a perennial plant with a tall pseudo stem formed by the encircling of leaf sheaths wrapped one over the other. Depending on the variety, a normal fully grown plant may reach 2–4 m in height. The genus name comes from *Elettaria*, the vernacular name for this plant in Malabar, India.

4.4.1.1 Appropriate Agronomic/Climatic Conditions (MFPI)

Annual Rainfall: 1500–4000 mm
Temperature: 10–35 °C
Altitude: 600–1200 m above the Mean Sea Level
Season: December to June
pH: 5.5 to 6.5
Humidity: 75%

4.4.1.2 Essential Oil

The essential oil of cardamom capsules is responsible for the characteristic aroma of cardamom. The essential oil yield and chemical constituents of 22 different accessions of cardamom have been evaluated and reported (Ashokkumar et al., 2020). The essential oil yield was from 4.5% to 9.5%, indicating substantial variations. The GC/MS analysis results discovered 24 constituents that constituted 98.1%–100% of total essential oil. The main fractions were "oxygenated monoterpenes (40.7%–66.7%), monoterpene hydrocarbons (23.1%–58.6%), and sesquiterpenes (0.1%–2.0%). Among the monoterpenoids, the predominant constituents were α-terpinyl acetate (29.9%–61.3%) followed by 1,8-cineole (15.2%–49.4%), α-terpineol (0.83%–13.2%), β-linalool (0.44%–11.0%), and sabinene (1.9%–4.9%). Two sesquiterpene constituents, cardinen, nerolidol, and *p*-cresol (a phenol derivative), were identified. The compositional data were subjected to euclidean-distance-based similarity analysis, which showed two major clusters. The major constituents of cardamom essential oil (*CEO*) are 1,8-cineole, α-terpinyl acetate, sabinene, and β-linalool that could be used in food, aroma, and pharmaceutical applications. The researchers (Ashokkumar et al., 2020) have reported the minimum and maximum range, retention time, and retention index of essential oil compounds in 24 cardamom accessions (Table 4.1).

4.4.1.3 Sowing and Cultivation

The cardamom seeds are obtained from standard seed suppliers, sown and initially cultivated to prepare the seedlings in primary and secondary nurseries. The seedlings are then planted in pits of appropriate size dug in land fields, subsequently filled with compost and suitable soil. Cardamom is usually grown as a rainfall crop, but occasional sprinkling with water is also done for its better growth and enhanced yield. The compost mix of 25 t/ha, 75 kg N, 75 kg P and 150 kg K/ha (MFPI).

Table 4.1 Minimum and maximum range, retention time, and retention index of essential oil compounds in 24 cardamom accessions

No.	Compound	RTa	Rib	RIc	Area %		
					Minimum	Maximum	Mean
1.	α-Thujene	8.3	924	930	0.1	1.0	0.2
2.	α-Pinene	8.6	948	943	0.6	1.5	1.0
3.	Sabinene	9.6	969	975	1.9	4.9	3.5
4.	β-Pinene	9.8	974	979	0.2	0.5	0.3
5.	β-Myrcene	10.0	988	990	0.9	1.9	1.4
6.	3-Carene	10.6	1008	1011	0.1	0.7	0.1
7.	α-Terpinolene	10.7	1022	1022	0.1	1.9	0.3
8.	Limonene	11.1	1024	1029	0.9	9.4	2.3
9.	1,8-Cineole	11.2	1026	1031	15.2	49.4	34.5
10.	β-Cymene	11.3	1042	1030	0.1	0.7	0.2
11.	γ-Terpinene	11.9	1054	1059	0.2	1.4	0.4
12.	β-Linalool	13.0	1082	1087	0.4	11.0	2.0
13.	Terpinen-4-ol	15.2	1137	1137	0.4	3.2	1.8
14.	α-Terpineol	15.6	1143	1140	0.8	13.2	3.4
15.	β-Terpineol	15.7	1158	1159	0.3	2.7	0.8
16.	β-Citral	15.8	1174	1174	0.1	0.5	0.2
17.	Nerol 1	6.8	1228	1229	0.2	1.1	0.7
18.	Linalyl acetate	16.9	1231	1231	0.2	4.4	1.2
19.	α-Citral	17.3	1264	1267	0.1	0.6	0.2
20.	α-Terpinyl acetate	19.4	1333	1300	29.9	61.3 43.5	
21.	Geranyl acetate	19.9	1379	1381	0.1	2.3	0.9
22.	p-Cresol	22.9	1382	1385	0.2	9.0	1.0
23.	γ-Cadinene	23.3	1513	1513	0.3	0.4	0.1
24.	Nerolidol	24.2	1564	1563	0.1	2.0	0.7

Source: Ashokkumar et al. (2020)

aRT, Retention time; bRI, Retention index (experimental) on Rxi®-5 Sil MS column; cRI, Retention index in literature; Monoterpene hydrocarbons, 1–8 and 11; Oxygenated aRT, Retention time; bRI, Retention index (experimental) on Rxi®-5 Sil MS column; cRI, Retention index in literature; Monoterpene hydrocarbons, 1–8 and 11; Oxygenated

4.4.1.4 Growth

The cardamom plants start bearing two to three years after planting. Panicles appear from the base of the plants; it is generally starting to appear in January. The flowering starts in August. The peak stage of flowering is May to June. The time for fruit to mature is about 120 days after flowering. Fruits are small trilocular capsules containing 15–20 seeds. On maturity, seeds turn dark brown to black.

4.4.1.5 Harvesting

The harvesting starts in August–September and extends into February–March. Matured cardamom capsules are picked up by hand. The yield ranges from 200 to 250 kg per hectare.

4.4.1.6 Genome

Anjali et al. (2016) conducted the variation in *Elettaria cardamomum* Maton (cardamom) based on genome size, cytological studies and molecular marker data. The relative 2C genome size and the number of base pairs of cardamom were determined through flow cytometric analysis using propidium iodide staining. The nuclear DNA content was estimated in various species sections representing individuals from wild and cultivar genotypes as the internal reference standard. Chromosome number from the growing root tip was examined following standard protocols. The chromosome number was found to be 2n = 48. Among the thirty cardamom accessions studied using ISSR markers showed a very prominent level of genetic diversity. Thus the analysis revealed the existence of genetic variability within the studied cardamom accessions. The plant specimens also differed significantly in their genome size.

According to a recent study by Nadukeri et al. (2020), cardamom is a cross-pollinated crop propagated through both vegetative and seed methods; thus, variability is present among its genotypes. Their investigation from the ANOVA statistical analysis showed that all growth characters exhibited significant differences at 1 and 5 percent levels except for the trait of leaf breadth. The results indicate that the "Phenotypic coefficient of variation was slightly higher than the genotypic coefficient of variation for all the growth characters. The highest GCV (23.5%) and PCV (24.3%) were recorded for the trait number of leaves per tiller. High heritability (99.0%) and genetic advance over a mean (48.2%) were noticed for the trait number of vegetative buds per clump."

4.5 Morphology of Stem

Though there are a few studies on the chemical characteristics of its leaf oil from other phytogeographical regions, the presence of oil in the stem and the chemical composition of essential oil from stems have not been reported in detail. However, a study was undertaken to characterize the chemical composition and antioxidant activity of leaf and stem essential oil of E. cardamom. The essential oil extracted by hydro-distillation from the leaf and stem revealed the presence of "43 and 37 compounds, representing 92.7% and 92.1% of total oil, respectively, by GC/MS analysis. The major constituents of the leaf essential oil were 1,8-cineole (20.6%), camphene (18.0%), camphor (10.0%) and tricyclene (7.36%), whereas α-terpinyl

acetate (19.7%), 1,8-cineole (10.3%), caryophyllene oxide (7.13%) and β-eudesmol (4.85%) were rich in the stem essential oil. Oxygenated monoterpenes were the major terpenic fraction in the leaf and stem essential oil of *E. cardamomum*. The free radical scavenging ability assessed by DPPH· (2,2-diphenyl-1-picrylhydrazyl) and ABTS (2,2-azinobis (3-ethylbenzothiazoline-6-sulfonic acid) assay showed that leaf oil had better activities as compared to stem oil. The findings demonstrated that *E. cardamomum* growing wild in Eastern India could be considered an important bioresource and natural antioxidant."

4.6 Morphology of Branches and Leaves

The structure of the branches and leaves of cardamom is shown in Fig. 4.4, and of leaves in Fig. 4.5.

Cardamom is a clumping plant with between 10 and 20 leafy shoots arising from the rhizome. There are several additional flowering shoots. The leaves are lanceolate and dark green. Cardamom is a pungent, aromatic, herbaceous perennial grown for its glossy textured foliage and edible use (Plant Finder). Cardamom is grown for

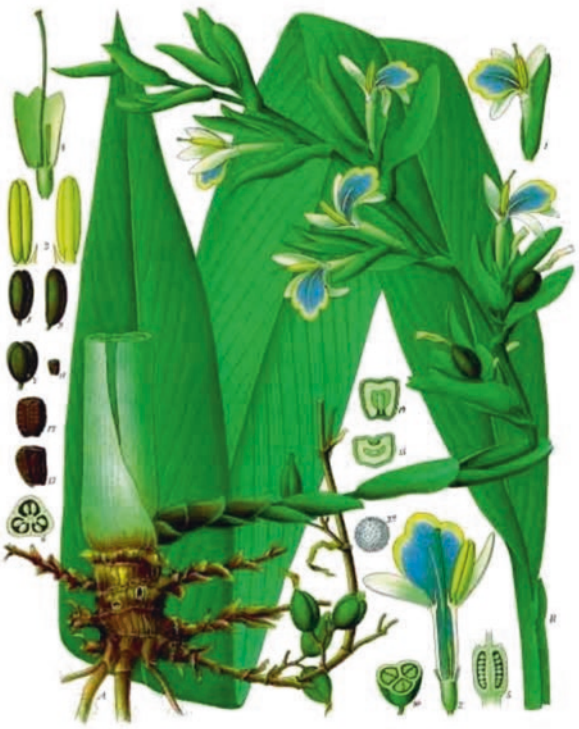


Fig. 4.4 Structure and morphology of branches and leaves

Fig. 4.5 Structure and morphology of leaves

its fruits used as a spice. Cardamom is a clumping plant with between 10 and 20 leafy shoots arising from the rhizome. The shoots are pseudo stems composed of overlapping leaf sheaths.

Cardamom leaves, like their pods and seeds, stand among the oldest and most expensive spices in their history on earth due to their unique flavor and aroma. In addition, the seeds and leaves have been used in cooking to prepare various delicious dishes. Cardamom is a ginger family member originating from India, Pakistan, and Nepal. The cardamom leaves bear the typical flavor of cinnamon and salt and have a freshening taste.

Cardamom leaves have also been used to make some excellent drinks. An important example is their fresh-tasting infusion. The leaves are used in sauces or stocks also. The products derived from cardamom leaves also combine very well with fish. Their warming brings out the best of its flavor.

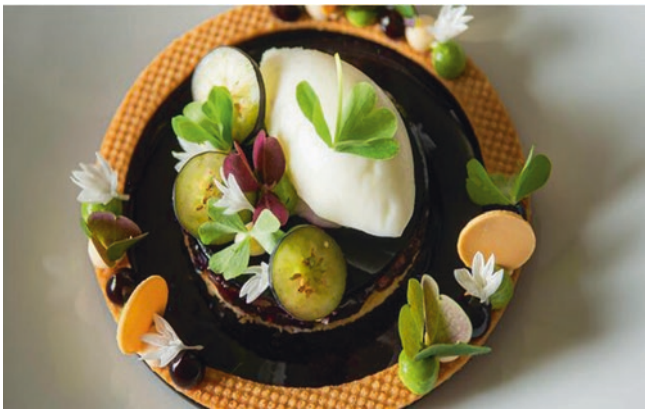
Cardamom Leaves are available annually and can easily be stored for up to seven days at a temperature of 2–7 °C. Cardamom leaves are produced in a socially responsible culture and meet hygienically designed kitchen standards. The product is ready for use because it is clean and is grown hygienically.

The spectrum of the products from cardamom leaves is very broad: "Blanching, Blending, Blitzing/Mashing, Bruising, Canning, Cold infusion, Confiture, Deep frying, Drying, Extracting, Fermenting, Freezing, Gvery broad, Grilling, Hot infusion, Macerate, Marinating, Oil, Pickling, Smoke, Sous vide, Steaming, Syrup Gin, Rum, Vodka, Chocolate, Coffee, Prawns, Lobster, Crab, Crustaceans others, Cod, Monkfish, Fish (saltwater), Banana, Berries, Blueberry, Cherry, Coconut, Kalamansi, Lime, Mandarin, Passion fruit, Plum, Granatapfel, Deer, Rabbit, Game, Mint, Anise, Beef, Goat, Lamb, Offals, Porc, Veal, Duck, Black pepper, Cinnamon, Vanilla, Beetroot, Ginger, Rhubarb, Couscous, Liquorice, Olive oil, Ponzu, Rice, Soy sauce, Sugar, Yuzu"

"Gin is a colorless distilled beverage widely consumed worldwide, produced by several methods, but always with juniper as the predominant taste. The volatile content of gin is made up of terpenoid compounds, mainly from juniper berries, but also from other botanicals such as coriander seeds, angelica root or citrus peel. Although some authors have used various methods to develop a vocabulary to describe the sensory characteristics of gin, no uniform vocabulary has been widely adopted. The most usual attributes defined by the tasters were juniper and coriander, but spice, liquorice, aniseed, floral and fruity attributes were also reported."

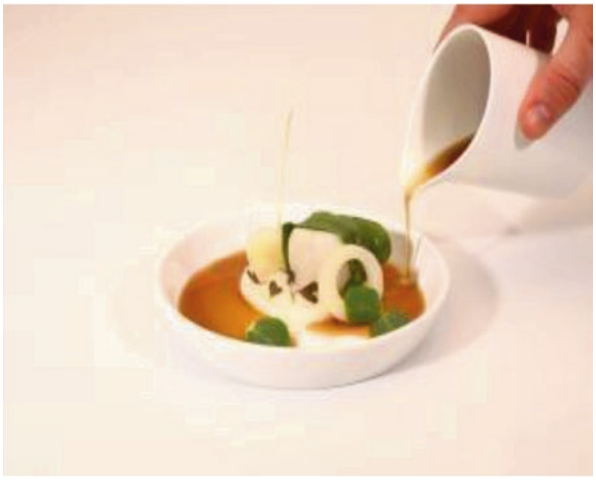
Sensory evaluation and consumer research of beverages of alcoholic beverages have been conducted (Woodward, 2012).

The images of some related recipes are given below.



Chocolate, ginger ice cream & olive crunch, lemon cress and cardamom leaves (**Jan Hartwig & Thomas Barosch**)

Pig's chin, cardamom leaves, bell pepper and celeriac (**Marcel Fischer**)



Steamed cardamom leaves with scallops

Spicy shakerato (**Lisette Dawtrey**)

4.7 Structure and Composition of Seeds

The structure and composition of the seeds are exhibited in Fig. 4.6.

The basic physical properties of cardamom seeds, such as length, width, thickness, geometric mean diameter, thousand seed mass, and sphericity, have been reported as dependent on their moisture content, according to a report from India (Gebreselassie, 2012). These were studied at moisture content 9.90%, 13.5%, 18.4%, and 23.2% on a wet basis and are reported "to increase from 17.01 to 17.30 mm, 5.68 to 6.57 mm, 5.02 to 5.35 mm, 7.86 to 8.47 mm, 120.8 to 165.6 g, and 0.46 to 0.49, respectively, with the increase in the moisture content from 9.9% to 23.2% n weight basis. As the moisture content increased from 9.9% to 23.2%, the bulk density, true density, and porosity decreased from 408.2 to 358.9 kg/m^3, 926.5 to787.1 kg/m^3, and 55.9% to 54.4%, respectively. In addition, the angle of repose increased from 72.16° at 9.9% to 73.80° at 23.2% moisture content. In contrast, the static coefficient of friction increased with the increase in moisture content from 9.9% to 23.2% on three different surfaces. The highest static coefficient of friction was recorded when cardamom seed against plywood (0.47–0.56), and the lowest static coefficient of friction against mild steel (0.41–0.50). The static coefficient of friction between cardamom seeds and galvanized iron surface increased from 0.44–0.53 within the studied moisture content range."

Cardamom seeds are widely used to make many products, including dishes and medicines. The major use of cardamom seeds is in preparing cardamom tea, a herbal tea made from the seed pods of the cardamom plant, including both its types: Green cardamom and Black cardamom. Green cardamom seeds come from

Fig. 4.6 Structure of cardamom seeds

the pods of the plant *Elettaria cardamomum. The* lack of cardamom comes from the plant *Amomum cardamomum*. *The former claims* an intensely strong flavor that is both spicy and slightly sweet. Black cardamom tea has a smoky flavor contrasted by a refreshing, slightly minty aroma. The seeds can be poured directly into hot water or cardamom powder. Cardamom seeds are picked by hand and may be used even in the raw state to make tea or after harvest in October. They are then either crushed or packaged as desired to make tea. The cardamom seeds can also be packed as tea bags and floated into the market for sale as culinary spices, as shown in the images below.

Benefits of Cardamom Tea

Cardamom tea has long been used in South Asia to treat various ailments. Like Indian masala chai tea, cardamom tea is an Ayurvedic and traditional medicine staple. Today, research shows that cardamom may have health benefits when consumed

regularly. Thus, let us know how to brew cardamom tea. About 2 cups of water are heated in a stovetop pot to prepare cardamom tea. The water is brought to a boil, removed from the stove, and 4 cardamom pods are added. Tea leaves are added to this s if they are used in planting. The contents of the pot top are steeped for 5 min before adding milk or sugar. A long reading is requisite to know the complete spectrum of tea health benefits of cardamom tea. Its major medical benefits are outlined below

1. Cardamom tea may aid weight loss and prevent severe obesity disease. Cardamom tea may help accelerate weight loss by streamlining the body's digestive processes. Thus it helps prevent fat buildup while helping the liver dispose of waste products more quickly. Ground cardamom helps prevent obesity. In a study on animals published in Lipids in Health and Disease (Rehman et al., 2017), the research workers found that cardamom improved glucose intolerance and prevented the deposit of abdominal fat. Cardamom was also shown to affect the liver by ameliorating fibrosis positively. Another study published in the Journal of Diabetes and Metabolic Disorders examined the effects of cardamom on pre-diabetic women. The researchers observed that cardamom consumption increased insulin sensitivity and decreased bad LDL cholesterol.
2. Cardamom tea is good for oral health. It helps in protecting dental health by inhibiting bacterial growth (Chen et al. 2020). The bacterial growth on the surface of the teeth causes dental caries, a commonly encountered disease due to the breaking of tooth enamel by acids. In addition, the bacterial fermentation of carbohydrates produces acids. Drinking cardamom tea can help neutralize the acids produced by bacteria and prevent plaque buildup, cavities, and dental caries. In addition, the anti-bacterial properties of cardamom also effectively treat halitosis, commonly known as bad breath. Bad breath is caused when bacterial buildup in the mouth begins and tends to feed on food particles. Cardamom helps eliminate bacteria to keep the breath fresh all day.
3. It may help in quitting smoking. Cardamom tea may be beneficial for those who are trying to quit smoking. Research published in Addictive Behaviors examined the potential of cardamom gum to aid nicotine withdrawal. The results showed that vanilla and baked apple cardamom gums effectively reduced nicotine withdrawal symptoms, including dysphoria, anxiety, and tension (Cohen, 2010).
4. It boosts the immune system. Like many herbal teas, cardamom tea may help treat and prevent the common cold and flu. It contains antioxidants and vitamins that fight off viruses, fungi, and bacteria. A study published in Ethnobotanical Leaflets found that cardamom may effectively prevent viruses such as streptococcus, which causes sore throat. In addition, researchers found cardamom effective against staph infections and fungal infections, including candida (Majdalawieh & Carr, 2009).
5. It protects heart health. Cardamom contains high levels of potassium that are good for heart health (Rastogi, 2017). Potassium is a vasodilator, decreasing inflammation and pressure on arteries and blood vessels. This means that drink-

ing cardamom tea regularly may help lower high blood pressure. As a result, it could help improve blood circulation and lower your risk of heart attack and blood clots.

6. It acts as a digestive aid. Cardamom tea has long been used as a digestive aid to soothe stomach ailments, including gas and bloating. It was used in Turkey and Arabic societies to treat intestinal worms. Crushed cardamom seeds have anti-inflammatory properties that soothe irritated stomach muscles. This helps to prevent the contractions that cause stomach pains. Cardamom is a natural carminative, which means it relieves gas. Drinking cardamom tea during or after meals can help streamline digestion and prevent gas. Some research also shows that cardamom tea may be beneficial in the treatment of irritable bowel syndrome, although results have been inconclusive (Streit, 2018).

Like ginger tea, cardamom tea can help treat nausea. Sip this hot tea before you board a boat or plane if you suffer from motion sickness. Drinking cardamom tea may also help ease morning sickness, but consult a physician before drinking cardamom tea if you are pregnant.

Side Effects of Cardamom Tea

Cardamom tea has not been shown to have any serious side effects when consumed in moderation. This herbal tea may interact with certain medications, so it is a good idea to talk to your doctor before drinking cardamom tea if you have a health condition. Research shows cardamom may interact with blood thinning medications and some antidepressants, so limit or avoid use if you take these medications.

Cardamom tea may cause allergic reactions in specific individuals. Therefore, stop using it immediately if you experience a runny nose, itchy throat, or difficulty breathing when drinking cardamom tea. Likewise, do not drink cardamom tea if you are allergic to either of the cardamom plants.

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