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Cardamom

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Abstract: Cardamom is one of the most expensive spices in the world. India's warm humid climate, loamy soil rich in organic matter, distributed rainfall and special cultivation and processing methods all combine to make Indian cardamom truly unique in terms of aroma, flavour, size and parrot green colour. Cardamon has well-established medicinal and culinary values, and is used in a wide range of sweets and confectionery. In this chapter, we have consolidated scientific information available on genetic improvement, varieties, horticultural technologies and post-harvest processing. Cardamom's uses in traditional medicine, pharmacological properties and applications in food industry are also discussed.

Key words: cardamom, *Elettaria cardamomum*, trade, botany, genetic improvement, varieties, nutrition management, harvest, post-harvest processing, value addition, essential oil, oleoresin, oil composition, uses, quality standards, grade specifications, adulteration issues.

8.1 Introduction

Cardamom of commerce, popularly known as 'Queen of Spices', is the dried fruit of the herbaceous perennial *Elettaria cardamomum* Maton, belonging to the Zingiberaceae family. It is a shade-loving plant cultivated at an altitude of 600–1200 m above mean sea level (MSL) with an annual rainfall of 1500–4000 mm and a temperature range of 10–35 °C. It is used in Ayurvedic medicine preparations because of its healing effect and other properties. It is also used in processed food, perfumes, oleoresins and many other applications. The genus *Elettaria* is one of the few compact natural groups of plants whose origin is the evergreen rainforests of South India and Sri Lanka (Purseglove *et al.*, 1981), from where it spread to other tropical countries. India was the main producer and exporter of cardamom until the 1980s, with Guatemala emerging later as a keen competitor to India in the international cardamom market. Tanzania, Sri Lanka, El Salvador, Vietnam, Laos, Cambodia and Papua New Guinea are also cardamom-growing countries. Cardamom was introduced to Guatemala in 1920, either from India or Sri Lanka (Lawrence, 1978). After World War II, cardamom production in Guatemala increased on account of high demand and a rise in the international price. The cultivation of cardamom has also grown in popularity in the virgin forest lands of Papua New Guinea, though it is restricted to private estate owners (Krishna, 1997). Cardamom is also cultivated in the East Usambara Mountains (4°48′132–5°13′ S and 38°32′–38°48′ E) of Tanzania (Myers

et al., 2000). Cardamom cultivation grew considerably in Sri Lanka during the 1960s, with the Knuckles region becoming the country's highest cardamom-producing area (Goonewardene, 2005).

8.1.1 History and importance

Cardamom is known to have been used in India since ancient times. It is known as *Ela* in Sanskrit and references to this can be found in ancient Sanskrit texts. Assyrian doctors and chemists were known to use many herbs, including cardamom (Parry, 1969). It was also mentioned that the ancient king of Babylon (721–701 BC) grew cardamom among other herbs in his garden. According to Watt (1972) it was one of the most popular oriental spices in Greek and Roman cuisine and, because of its importance, cardamom was listed as an item liable to duty at Alexandria in 176 AD.

Linschoten, in his *Journal of Indian Travels* (1596), describes two forms of cardamom used in South India (Watt, 1872). However, in general, early references to the use of cardamom are sparse in comparison to other spices, namely, black pepper, cinnamon and cassia.

The Arab states were the original major traders of Indian spices, including cardamom. Later, in the sixteenth century, the Portuguese started collecting and exporting pepper, ginger and cardamom directly to Europe. Only at the beginning of the nineteenth century were plantations established for cardamom cultivation, and even then they were only a secondary crop in coffee plantations. German settlers introduced cardamom to Tanzania in the 1890s. In 1954, Amani Botanical Garden in the Usambaras region distributed some seedlings to farmers, who vegetatively propagated and supplied to other farmers. After a decade, the cardamom trade began to flourish. Watt (1872) also briefly described cardamom cultivation in South India. The system of collecting cardamom from naturally growing plants continued until at least 1803 but, in later years, as demand increased large-scale organised cultivation began in India and Sri Lanka (Ridley, 1912). An example of this is the government of Travancore, India, who took up active cultivation of cardamom in 1823. Further information about cardamom cultivation can be found in the Madras Manual (Watt, 1872).

8.1.2 Production and trade in India and other countries

The present cardamom-growing tract in India lies between 8°30′ and 14°30′ N latitude and longitude of 75–70′E. It is an elongated tract from north to south extending over 2000 km, from Sirsi of the Karnataka region to Thirunelveli of the Tamil Nadu region. east to west, it is a narrow belt of land distributed over the Western Ghats (Madhusoodanan *et al.*, 1994). The important areas of cultivation include Nelliampathy, Wynad and Idukki, which are in the Travancore Cochin (*Malabar*) region of the Kerala state; Uttar Kannada, Shimoga, Hassan and Chickmagalur, which are in the hills of the Kodagu (Coorg) district in Karnataka; and the northern and southern foothills of Nilgiris, Didigul, Theni, Salem and Tirunelveli, which are part of the Coimbator district in Tamil Nadu.

In India, the amount of cardamom cultivated has fluctuated over the years (Table 8.1). Production rose from 2900 mt during 1987–8 to 10075 mt in 2009–10. During

Table 8.1 State-wise area and production of cardamom in India

States	1970–1		1980–1		1990–1		2000–1		2006–7	
	Area	Production	Area	Production	Area	Production	Area	Production	Area	Production
Kerala	55190	2130	56380	3100	43826	3450	41288	7580	41200	8500
Karnataka	28220	1000	28220	1000	31605	800	25947	2100	24000	1000
Tamil Nadu	8070	235	9350	300	6123	500	5085	800	4400	400
Total	91480	3365	93950	4400	81554	4750	72320	10480	69600	9900

Note: area in ha, production in MT.

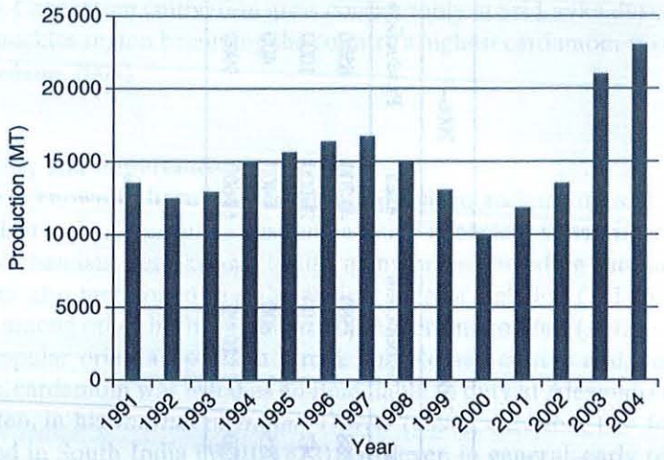

Fig. 8.1 Cardamom production in Guatemala (various publications of Banco De Guatemala and Spices Board, India).

this period, productivity increased from almost 41 kg/ha to 201 kg/ha. This productivity increase is due to the use of high-yielding varieties and improved agro techniques. However, the demand for exported cardamom reached a low point during the same period. The maximum export recorded (3272 mt) was during 1985–6, whilst the lowest amount exported (173 mt) was during the year 1989–90. During 2009–10, India exported 1975 mt, valued at Rs. 165.70 crores, in comparison to 500 mt, valued at Rs. 24.75 crores, exported in 2007–8.

Saudi Arabia accounts for 1117.7 mt (69 %) of Indian exports (2009–10) followed by UAE (296 mt), Kuwait (92.2 mt) and Egypt (71 mt). This can be accounted for by increased competition from other cardamom-producing countries, as well as a rise in domestic consumption (Joseph, 2010).

Presently, 90 % of the cardamom traded in the world comes from Guatemala (Fig. 8.1). During 2004, the production of cardamom in the country was 23 000 mt. In the Usambaras area of Tanzania, the main cardamom growers are the local Washambaa people and immigrants from the nearby highlands (Teija *et al.*, 2006). The average annual cardamom yield in the East Usambaras mountains is 80 kg/ha (Masayanyika 1995). The production levels in Tanzania and Sri Lanka are around 125 mt and 75 mt, respectively, per year (Ravindran, 2002).

8.2 Classification of cardamon

Cardamom (*Elettaria cardamomum* Maton) belongs to the natural order Scitaminae under the family Zingiberaceae. The genus *Elettaria* consists of a small number of spices distributed in India, Sri Lanka, Malaysia and Indonesia (Holtum, 1950; Wills, 1967; Mabbberley, 1987). Two botanical varieties have been distinguished based on the size of the fruits, one for the wild taxon and one for the cultivated forms:

1. *Elettaria cardamomum* var *major* Thw. comprising the 'wild' indigenous cardamom of Sri Lanka, also known as greater oblong cardamom or long cardamom.
2. *Elettaria cardamomum* var *minor* Watt (syn *Elettaria cardamomum* var *minuscula* Burtkill) comprising all the cultivated groups. This cultivated cardamom can be grouped into many cultivar groups, the two most important ones being *Malabar* and *Mysore* (Wardini and Thomas, 1999).

In addition to the two main varieties, a few more have been recognised. All the varieties and races are interfertile and the observed variations are probably due to natural crossing. Based on adaptability, nature of the panicle, shape and size of fruits, three types of cultivated small cardamom have been identified, viz., *Malabar*, *Mysore* and *Vazhukka* (Madhusoodanan *et al.*, 1994). Two more varieties, *mysorensis* and *laxiflora*, have been recognised based on some morphological characteristics.

A lot of confusion prevails over the botanical identity of Sri Lankan wild cardamom and the Indian cardamom varieties mentioned above. Various authors have named cardamom varieties differently:

- Sri Lankan wild cardamom: *Elettaria ensal* Abheywickrama (*E. major* Thawaites) (Madhusoodanan *et al.*, 2002);
- Malaysian and Indonesian: *Elettaria longituba* (Ridl.), (Holttum, 1950).

The vernacular name 'cardamom' is also often also used for many other taxa, particularly *Amomum* species.

8.2.1 Botany

Cardamom is an herbaceous perennial (2–5 m in height) with underground (subterrain) rhizomes, with aerial pseudo stems (tillers) made of leaf sheaths. Studies of vegetative growth indicate that suckers continue their growth for a period of about 18 months from time of emergence. The rate of linear growth is at its maximum during June and July, when the suckers have attained an age of about one year. The development of reproductive buds (panicles) can be seen in 89 % of them, indicating that the suckers require about 10–12 months to attain maturity. It takes almost ten months for a vegetative bud to develop and about a year for the panicle to emerge from the newly formed tillers (Sudharsan *et al.*, 1988). Kuruvilla *et al.* (1992) carried out a round-the-year study on the phenology of the tiller and panicle in three varieties of cardamom. They found that it took around 90–100 days for the emergence of the first flower from the panicles, irrespective of the variety.

The inflorescence is a long panicle with racemose clusters rising from the underground stem, but coming up above the soil. Pattanshetty and Prasad (1976) and Parameswar (1973) have made detailed observations on panicle production; its growth, duration of flowering, etc. The linear growth of the panicles extends over a period of about seven months. The rate of growth is at its maximum during April, and is slower during the earlier and later stages. The growth habit of the panicles and the shape and size of the capsules vary in different cultivated varieties/types of cardamom (Table 8.2). These panicles either grow erect (*Mysore*), prostrate (*Malabar*) or in a semi-erect manner (*Vazhukka*). Multiple branching (compound panicle) of panicles appears in certain cultivars. In such cases, the central peduncle

Table 8.2 Characteristic features of three cardamom types

Characters	*Malabar*	*Mysore*	*Vazhukka* (natural cross between *malabar* and *mysore*)
Adaptability	Lower altitudes 600–900 m MSL	Higher altitudes 900–1200 m MSL	Wide range
Areas of cultivation	Karnataka	Kerala and parts of Tamil Nadu	Kerala
Plant vigour	Medium	Robust	Robust
Panicles	Prostrate	Erect	Semi-erect
Capsules	Round or oblong	Bold, elongated	Round to oblong
Leaf petiole	Short	Long	Long
Capsule colour at maturity	Pale/golden/yellow	Green	Green

undergoes further branching of secondary and tertiary branches producing compound panicle types.

Flowers appear on the panicle after four months and flowering continues for a period of six months. Each flower cluster is a cincinnus (Holttum, 1950). The characteristics of the flowers are listed below:

- The flowers are bisexual.
- The bracts are linear, oblong and persistent.
- There are three racemose sepals.
- They have three petals, which are unequal and have a longer lip with three violet carpels.
- There is one style.
- The ovary is trilocular and is of axile placentation.
- There are numerous ovules in each carpel.

Pai (1965) has concluded from anatomical evidence that the labellum is a double structure, whereas Parameswar and Venugopal (1974) are of the view that the labellum is made up of three modified anthers.

Normally, flowering in cardamom is seen throughout the year on panicles produced during the current year, as well as on panicles produced during the previous year. The peak flowering is spread over a period of six months between May and October. The time required from flower/bud initiation to full bloom stage ranges from 26 to 34 days. Capsule development takes about 110–20 days from the full bloom stage (Krishnamurthy *et al.*, 1989).

The early hours of the day are when the maximum number of flowers open. Anthesis follows immediately. In the Mudigere region of Karnataka, flowering commences at 3.30 am and continues until 7.30 am. The dehiscence of anthers takes place immediately followed by anthesis at 3.30 am which continues up to 7.30 am. The maximum pollen bursting occurs between 5.30 am and 6.30 am. The pollen grains are round and mostly found individually. They measure on average 87.6 μ in diameter. By appearance, 85.2 % of the pollen grains are fertile, but a maximum of

70.1 % germinate on an artificial medium, containing 20 % sucrose and 1 % agar. Studies of the viability of pollen grains indicate that only 6.5 % remain viable after 2 hours of storage. After 6–8 hours of storage, the percentage of viability was practically zero (Krishnamurthy *et al.*, 1989). Pollen fertility is maximum at full bloom stage, and low at the beginning and end of the flowering periods (Venugopal and Parameswar, 1974). With respect to pollen morphology, the three varieties of cardamom are round in shape and the pollen mass appears as a creamy powder. The largest pollen grains are observed in *Mysore* variety, while the smallest are found in *Vazhukka* variety.

Even though cardamom has bisexual flowers and is self-compatible, cross-pollination is common. Self-pollination is hindered due to the slight protrusion of the stigma above the stamens. In cardamom, cross-pollination is mediated by the activity of bees (*Apis cerana*, *Apis indica* and *Apis dorsata*) who act as pollinators. Cardamom flowers remain in bloom for 15–18 hours per day. Stigma receptivity and pollen viability are at maximum during the morning hours. Receptivity is at maximum between 8 am and 10 am, when 72 % of the opened flowers set fruit. After 10 am the stigma receptivity decreases gradually and only 24 % of the flowers opening at 4 pm set fruit. It is reported that receptivity of the stigma is highest between 8 am and 12 noon (Krishnamurthy *et al.*, 1989; Kuruvilla and Madhusoodanan, 1988). Parvathi *et al.* (1993) and Belavadi *et al.* (2000) noticed that the peak receptivity around 12 noon coincides with peak pollinator activity. The active foraging of bees is mainly seen in the morning hours; this activity is instrumental in increasing the fruit set in cardamom.

8.2.2 Cytology

The chromosomal numbers for cardamom are $2n = 48$ (Gregory, 1936; Sharma and Bhattacharyya, 1939) and $2n = 52$ (Chakravarti, 1948). Cardamom is considered to be a balanced tetraploid. Allied genera such as *Globa*, *Balbifera*, *Phoemaria*, *Amomum* sps and *Alpinia* sps also possess $2n = 48$ and are considered to be evolved from a common basic number, $x = 12$. The *Mysore* and *Malabar* varieties of cardamom possess $2n = 50$ and $2n = 48$ chromosomes, respectively, and aneuploidy as well as structural alterations in the chromosome have contributed to the varietal differentiation (Chandrasekhar and Sampathkumar, 1986). Earlier researchers (Chandrasekhar and Sampathkumar, 1986) have reported that cardamom is of amphidiploid origin from wild species, and the two species considered to be the putative parents are the Sri Lankan cardamom *E. major* and the Malaysian species *E. longituba*.

8.3 Genetic improvement and varieties

Six research organizations in India – *viz.*, Indian Institute of Spices Research (ICAR), Cardamom Research Centre, Appangala, Karnataka; Indian Cardamom Research Institute (ICRI), Myladumpara and its Regional Research Station, Sakleshpur, Karnataka; Regional Research Station, Mudigere (UAS, Bangalore) and

Cardamom Research Station, Pampadumpara (KAU, Kerala) – are presently engaged in research for the improvement of cardamom. Regular surveys are being undertaken by these institutions, gathering the variable germplasm and exploiting the desirable genes of these accessions through various crop improvement techniques. The collections of a large number of indigenous lines are being conserved in different centres. In 1994, a detailed descriptor on cardamom was published by the International Plant Genetic Resources Institute (IPGRI), presently Bioversity International, Rome, Italy (IPGRI, 1994). Among the different cardamom-growing countries, India has a very strong research base.

Breeding methods such as selection, hybridisation, mutation breeding and polyploidy breeding have been employed in cardamom improvement. The major objectives of the crop improvement program in cardamom (IISR, 2007) are:

- to develop varieties having wider adaptability to different agro-ecological conditions;
- to evolve high-yielding genotype with superior capsule characters;
- to breed varieties having resistance to biotic stress such as, thrips, root grub, nematodes, fungal (rhizome rot) and viral diseases(*katte* and *kokke kandu*);
- to evolve drought-tolerant high-yielding varieties.

8.3.1 Clonal selection

The improved varieties have been evolved by selecting superior plants with desirable characteristics such as higher yield and superior capsule characteristics from land race populations. The highly heterozygous nature of the crop and the ability to multiply selections by clonal propagations has contributed to this success. Selections are made '*in situ*' in planters, fields and forests. The selected plants are multiplied clonally, subjected to preliminary evaluation and subsequently evaluated in a comparative yield trial and a multi-location trial to confirm their superiority and adaptability. Selection of cardamom is highly location-specific to their agro-ecological requirements. The improved selections are much superior to the local clones with regard to yield and capsule characteristics (Venugopal and Prasath, 2003; Prasath *et al.*, 2009a). Salient features of varieties in vogue are summarised in Table 8.3.

8.3.2 Intervarietal hybridization

Since cardamom is amenable to both sexual and vegetative propagation, hybridisation is a very useful tool for crop improvement. Research at various institutes has led to the isolation of high-yielding recombinants and heterotic hybrids. Bhat *et al.* (2010) reported a novel hybridisation technique, known as the straw tube technique, for simple, easy and effective hybridisation. The diallel cross-combinations were more vigorous compared to the parental lines (Krishnamurthy *et al.*, 1989). Madhusoodanan *et al.* (1998, 1999) reported few high-yielding heterotic recombinants. The elite selections were compatible with each other; however, the degree of compatibility varied with the parents selected for hybridisation (Venugopal and Padmini, 1999). Padmini *et al.* (2001) observed hybrid vigour in seedlings of cardamom with regard to plant height, number of leaves per plant,

Table 8.3 Cardamom varieties released for various useful traits in India

Variety	Year of release	Breeding method	Pedigree/parentage and plant type	Important traits	Institute/ university
Mudigere 1	1984	Selection	Clonal selection from *Malabar* type	Erect and compact plant, short panicle, pale green, oval bold capsules, suitable for high-density planting, moderately tolerant to thrips, hairy caterpillar and white grubs, pubescent leaves. Contains oil 8.0 %, 1,8-cineole 36.0 %, α-terpenyl acetate 42.0 %, dry recovery 20.0 % with 275 kg dry/ha	Regional Research Station, UAS, Mudigere
Mudigere 2	1996	Selection	Clonal selection from open pollination of *Malabar* type	Early maturing, suitable for high-density planting, round/oval and bold capsules. Contains oil 8.0 %, 1,8-cineole 45.0 %, α-terpenyl acetate 38.0 % with 475 kg dry/ha	Regional Research Station, UAS, Mudigere
PV 1	1991	Selection	A selection from Walayar collection, a *Malabar* type	An early maturing type, short panicle, elongated slightly ribbed light green capsules. Contains oil 6.8 %, 1,8-cineole 33.0 %, α-terpenyl acetate 46.0 %, dry recovery 19.9 % with 260 kg dry/ha	Cardamom Research Station, KAU, Pampadumpara
PV 2	2001	Selection	A selection from OP seedlings of PV-1, *Malabar* type	Early maturing, unbranched lengthy panicle, long bold capsules, high dry recovery percentage (23.8 %), essential oil 10.45 %, field tolerant to stem borer and thrips. Suitable for elevation range of 1000–1200 m above MSL with 982 kg dry/ha	Cardamom Research Station, KAU, Pampadumpara
ICRI 1	1992	Selection	Selection from Chakkupallam collection, *Malabar* type	An early maturing variety, medium sized panicle with globose, round and extra bold dark green capsules. Contains oil 8.7 %, 1,8-cineole 29.0 %, α-terpenyl acetate 38.0 %, dry recovery 22.9 % with 325 kg dry/ha	ICRI (Spices Board), Myladumpara
ICRI 2	1992	Selection	Clonal selection from germplasm collection, *Mysore* type	Performs well under high-altitude and irrigated condition, medium long panicles, oblong bold and parrot green capsules, tolerant to azukkal disease. Dry recovery 22.5 % with 375 kg dry/ha	ICRI (Spices Board), Myladumpara

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Table 8.3 *Continued*

Variety	Year of release	Breeding method	Pedigree/parentage and plant type	Important traits	Institute/ university
ICRI 3	1993	Selection	Selection from *Malabar* type	Early maturing, non-pubescent leaves, tolerant to rhizome rot disease, oblong, bold parrot green capsules, suitable for hill zone of Karnataka. Contains oil 6.6 %, 1,8-cineole 54.0 %, α-terpenyl acetate 24.0 %, dry recovery 22.0 % with 440 kg dry/ha	ICRI (Spices Board) Sakleshpur
ICRI 4	1997	Selection	Clonal selection from Vadagaraparai area of lower pullenys, a *Malabar* type	Early maturity, medium-sized panicle, globose bold capsules. Contains oil 6.4 %. Suitable for low-rainfall areas, relatively tolerant to rhizome rot and capsule borer with 455 kg dry/ha	ICRI (Spices Board), Myladumpara
ICRI 5	2006	Hybridization	MCC260 X MCC 49	First hybrid variety; early maturity, moderately tolerant to drought, high yield under intensive management (responds well to intensive management). Capsule size – bold 68 % (with more than 7 mm), oil – 7.13 %; dry recovery – 23.15 %	ICRI (Spices Board), Myladumpara
ICRI 6	2006	Selection	Clonal selection	High yield, medium maturity, relatively tolerant to drought, high percentage of bold capsules and volatile oil content. Capsule size – 71 % with more than 7 mm; volatile oil – 7.33 %; dry recovery – 19.0 %	ICRI (Spices Board), Myladumpara
IISR Suvashini	1997	Selection	Clonal selection from OP progenies of Cl.37	*Malabar* type, early maturing. The variety has an average yield of 745 kg/ha. In few high-production plots, yield as high as 1775 kg/ha has been achieved	IISR, CRC, Appangala
IISR Avinash	1999	Selection	Clonal selection from OP progenies of CCS-1	*Malabar* type, tolerant to rhizome rot, shoot and capsule borer, average yield of 847 kg/ha (potential yield of 1483 kg/ha). It has an extended flowering period.	IISR, CRC, Appangala
IISR Vijetha	2001	Selection	Clonal selection from Natural *katte* escapes (NKE 12)	*Malabar* type, resistant to *katte* (Cardamom mosaic virus). It has an average yield of 643 kg/ha. The potential yield of this variety is 979 kg/ha.	IISR, CRC, Appangala

leaf length and breadth. The hybrids MHC 18, MHC 10 and MHC 12 showed vigour with regard to yield and yield-contributing characteristics (Pradipkumar *et al.*, 2002). Appreciable heterosis was recorded over the standard parent, with desirable yield characteristics and high-yielding mosaic-resistant hybrids were identified (Prasath *et al.*, 2009b). Genetic analysis of diallel hybrids revealed the influence of dominance and over-dominance in the manifestation of quantitative characteristics (Prasath and Venugopal, 2002). The resistance of the cardamom plants to CdMV (cardamom mosaic virus) is quantitative, with possibly two major factors, and is dependent on gene dosage with completely dominant gene action (Prasath *et al.*, 2010).

8.3.3 Polycross breeding

Chandrappa *et al.* (1998) carried out studies on the impact of selection in a polycross progeny population. Since cardamom is a cross-pollinated crop, the polycross method of breeding is ideal to evolve superior types. Elite clones, having predominantly desirable characteristics, are planted together on an isolated plot. Beehives are maintained in the plot for assured pollination so that maximum fruit set and a high number of seeds per capsule can be obtained.

8.3.4 Intergeneric hybridisation

Although a few improved high-yielding varieties of cardamom have been evolved, combining yield and cardamom mosaic resistance has not been possible. To achieve this objective, intergeneric crosses were made using *Ammomum subulatum*, *Alpinia neutans*, *Hedychium flavascene* and *Hedychium coronarium* as male parents. A few fruits have been obtained in the cross involving *Alpinia neutans*; in other crosses no seeds were set (Parameswar, 1997). Therefore, the results of intergeneric crosses are not encouraging (Krishnamurthy *et al.*, 1989, Madhusoodanan *et al.*, 1990). Compatibility barriers prevented the formation of fruits in these cross-combinations (Madhusoodanan *et al.*, 1990).

8.3.5 Mutation breeding

To develop clones tolerant to the cardamom mosaic (*katte*) virus, drought seeds and rhizomes of cardamom have been subjected to x-rays, nitrosomethyl urea (NMU), diethyl sulphate (DES) and ethyl methane sulphate (EMS). No desirable mutant has so far been obtained. However, sterility and lack of macromutations in the M1 generation (ICRI, 1987) were also reported.

8.3.6 Polyploidy breeding

Polyploids were induced in cardamom by treating the sprouting seeds with 0.5 % aqueous solution of colchicine. The tetraploid lines exhibited an increase in the layers of epidermal cells, a thick cuticle and a thicker wax coating on the leaves. These characteristics are generally associated with drought tolerance (Sudharsahan, 1989).

8.4 Production of cardamom: horticultural technologies and nursery management

Cardamom is propagated either through seeds or vegetative means and, being a cross-pollinated crop, the seedling population is not uniform. Only 35 % of the plants are good yielders in a plantation raised from a seedling population (Krishnamurthy *et al.*, 1989). Hence, vegetative propagation is normally adopted for multiplication of elite clones. Vegetative propagation can be either through suckers or tissue culture.

The seeds are collected from fully ripe capsules, preferably from the second to third round of harvest in September. The seeds are then either washed in water and sown immediately or mixed with wood ash and dried for 2–9 days at room temperature. Storage of seeds results in loss of viability and delay in germination. Immediate sowing results in maximum germination. Germination has been shown to be at its highest (71.8 %) when sown in September (Pattanshetty and Prasad, 1973; Pattanshetty *et al.*, 1978). Cardamom seeds sown immediately after harvest (September) germinate uniformly, and seedlings are ready for transplanting at the end of the tenth month. The ideal sowing season has been reported to be November–January for Kerala and Tamil Nadu, and September for Karnataka.

Germination is significantly correlated with maximum and minimum temperature prevalent in the area (Gurumurthy and Hegde, 1987), as the seeds fail to germinate at a temperature less than 15 °C and greater than 35 °C. The germination is optimum at 30 C (70.9–73.0 % RH) with the highest percentage during September–October (Siddagangaiah *et al.*, 1993). The optimal light requirement for a cardamom nursery was found to be 55 % of the normal (Ranjithakumari *et al.*, 1993). This intensity was found to produce better growth and development of seedlings in the nursery. Mulching of seedbeds also influenced the germination of seeds. Mulching with coir dust, paddy straw and dry sal leaves enhanced germination (Sulikeri and Kololgi, 1978).

Seedlings at the four to five leaf stage from the primary nursery beds are transplanted to the secondary nursery, and set at a distance of 20–25 cm or in polythene bags (20 × 20 cm). In Karnataka, where seeds are sown during August–September, transplanting in the secondary nursery is done during November–January. In Kerala and Tamil Nadu, seedlings from primary beds are transplanted to secondary nursery beds at a spacing of 20 × 20 cm during June–July. The rate of mortality can be minimized by transplanting at the four–five leaf stage (Ankegowda, 2008).

Seed treatment with *Trichoderma* is desirable as a prophylactic measure for managing nursery rot diseases. At the time of preparation of the beds, incorporation of vesicular arbuscular mycorrhiza (VAM) multiplied in an organic medium is recommended. The potting mixture, 3:1:1 soil rich in organic matter, well-rotted cow dung or vermicompost and sand, is prepared for raising polybag seedlings. VAM and *Trichoderma* can also be added to the potting mixture (250 g mixed with 25 kg of well-rotted cow dung). Spraying with vermiwash once a month is desirable to enhance seedling growth. The diseases in the nurseries are best managed by regular surveillance and by adopting phytosanitary measures. Restricted application of Bordeaux mixture 1%, may be done to control root rot disease at the initial stage.

Changing the nursery site can be of benefit to ward off pests and diseases, and it can also encourage vigorous growth of seedlings (Anon., 1998).

High-yielding varieties are multiplied in isolated clonal nurseries. The virus-free high-yielding plants are selected and subcloned for further multiplication. Rapid clonal multiplication is standardised in cardamom for large-scale multiplication (Korikanthimath, 1997).

8.5 Production of cardamom: planting and aftercare

8.5.1 Site selection and shade requirement

The shade canopy provides a suitable environment by maintaining humidity and evaporation at suitable levels. The shade requirements vary from place to place and depend on the lay of land, soil type, rainfall pattern and crop combination, etc. Cardamom yield level is highest under 65–70 % light intensity (Sulikeri, 1986), whereas total biomass, phytochemical activity, chlorophyll and protein contents are adversely affected under full light (100 %), when compared to medium light (45–55 %) (Ravindran and Kulandaivelu, 1998). Plant growth has been shown to be reduced by 40 % under full light, compared to those exposed to medium light. The photosynthetic efficiency appears to be greater under low light intensities (30.6–106.63 μE/m^2/sec) (Vasanthkumar *et al.*, 1989). In Tanzania, farmers leave 75–100 shade trees/ha to provide shade for optimum production of their crop (Masayanyika, 1995).

8.5.2 Main field preparation

Cardamom is generally cultivated in forest areas with an overhead umbrella canopy to take advantage of filtered shade. If the land is slanted, it is advisable to start cleaning from the top and work downwards. For slopes, adequate soil and water conservation measures are necessary whilst preparing the land for planting. Planting in trenches across the slopes in low rainfall areas, diagonal planting and soil mulching result in better soil and water conservation. Nair (2006) has presented a comprehensive review of various aspects of the agronomy and economy of cardamom.

8.5.3 Spacing

Spacing is decided based on variety and duration of crop. The *Mysore* and *Vazhukka* varieties are vigorous and need wider spacing, whereas *Malabar* types need closer spacing. High yield was recorded in cardamom seedlings planted at 2 × 1 m in hill slopes and 2.1 × 2.1 m in flat lands (Korikanthimath and Venugopal, 1989). The trench method of planting with a spacing of 2 × 1 m resulted in better growth and yield (Siddagangaiah *et al.*, 1998). In general, *Mysore* and *Vazhukka* types are planted at a spacing of 3 × 3 m or 2.4 × 2.4 m in high rainfall or irrigated areas. A spacing of 1.8 × 1.8 m or 2 × 2 m is suitable for the cardamom-growing areas of Karnataka.

8.5.4 Method of planting

The trench method of planting (60 × 30 cm) with a spacing of 2 × 1 m resulted in the maximum growth and yield, with a greater moisture retention than the pit system of planting. *Mysore* and *Vazhukka* types are usually planted in the pits of 90 × 90 × 45 or 90 cm, whereas 45 × 45 × 45 cm pits, which are generally opened during April–May after pre-monsoon showers, are used for planting *Malabar* types. Pits are filled with a mixture of topsoil, compost or well-rotted farmyard manure (FYM) and 40 g of rock phosphate.

8.5.5 Planting season

Planting season is based on topography and rainfall pattern, and planting is normally done in June–July. In areas receiving a heavy south–west monsoon (July–September), planting is either completed before July or is taken up in August–September in order to avoid heavy rains in July. Early planting gives better establishment and growth than late planting. Planting in low lying areas (such as valleys) should be done only after heavy rains in July. Better establishment and growth of seedlings have been recorded in August planting in Mudigere, Karnataka (Pattanshetty and Prasad, 1972). Cardamom suckers are planted from June–August on the surface or 15–20 cm below the surface. During planting, a minimum of 320 mm rainfall along with temperature range of 15.5–17.5 °C (minimum) and 19.5–25.0 °C (maximum) is required for better establishment.

8.5.6 Planting

Cardamom seedlings 10–18 months old are planted in pits by taking a small portion of filled soil and adding rock phosphate (40 g). Soil is then replaced, taking care that the roots are distributed in their normal position, and well pressed around the base of the clump. It is advisable to plant just above the ground level to avoid rotting during heavy rains. Seedlings are normally planted in a pit at an acute angle to promote shoot production. Light root pruning is required once the seedlings reach 18 months old. In the case of suckers, they should be planted in a slanting position and with the base of the rhizome covered with soil. After planting, cross-staking is required immediately to avoid wind damage. After transplanting, care should be taken to offset the transplanting shock and to save the seedlings from heavy rains.

8.5.7 Mulching

Mulching is done to reduce evapotranspiration and rain damage. The fallen leaves from the shade trees can be used for mulching. Sufficient mulching should be undertaken during November–December to overcome drought during summer. De-mulching is also equally important during May or after the pre-monsoon showers to facilitate honeybee movement for better pollination and capsule setting. It also provides better aeration and minimises incidences of clump rot or rhizome rot. The practice of uncovering the panicles shortly after the commencement of flowering improves fruit set in cardamom.

8.5.8 Weeding and trashing

Clean weeding is to be limited to the plant bases (50 cm), the inter-rows are to be maintained by slash weeding. The weeded materials can be used for mulching, as can trashed materials and fallen leaves. The dry leaves and leaf sheaths should be trashed and the old suckers and rhizomes removed once a year, after completion of the final harvest.

These waste materials can then be used, for composting. Trashing thrice a year and cleaning the plant bases during monsoon months improves the chances of pollination, by eliminating breeding sites for sucking pests. This also reduces incidence of rhizome rot.

8.5.9 Irrigation management

Cardamom is generally grown as a rain-fed crop, and the cardamom tracts of India experience a dry spell of about 5–6 months. Increased denudation of forests and deterioration in forest ecology, coupled with erratic trends of rainfall, can lead to aridity, adversely affecting cardamom production (Rethinam and Korikanthimath, 1985). Since cardamom is a shallow-rooted crop, the moisture in the root zone is maintained by irrigating the crop from January to May (Sivanappan, 1985). Irrigation at 75 % available soil moisture (ASM) recorded favourable growth parameters compared to 25 % ASM (Raju, 1981). Cardamom plants irrigated at 25 % ASM and 75 % ASM produced 2.01 and 2.14 times more capsules, respectively, than those without irrigation. Irrigation at 75 % ASM combined with high levels of light resulted in the highest yield of 2618 kg/ha.

Sprinkler irrigation, equivalent to 4 cm rainfall at every 12–15 days, would be quite sufficient for cardamom crop (John and Mathew, 1977; Saleem, 1978). Daily drip irrigation, at 8 L per plant from 15 January, recorded a significantly higher yield and it was followed by sprinkler irrigation once every 12 days (IISR, 2004). In low- to medium-rainfall areas (1200–2000 mm), the trench system of planting was found to conserve soil moisture. In areas with a slope of more than 7 % all along the contour, bench terracing of about 1.5–1.8 m width is required for planting cardamom. Agronomical practices such as shade regulation, trenching, use of terrace systems, provision of shelter belts, mulching, earthing up, vegetative barriers and intercropping all aid better growth and development of cardamom, besides effective soil and water conservation measures. Although cardamom requires high moisture levels, it is sensitive to a high water table and the resultant waterlogged situations (Sulikeri and Kololgi, 1978).

8.5.10 Shade regulation

Shade requirement studies indicated that cardamom does not tolerate direct sunlight but, at the same time, too much shade affects its metabolic activities. Removal of excess shade is also essential to allow sufficient light penetration. Shade has to be regulated based on the topography of the land and moisture content, among other things, in order to achieve about 50 % filtered sunlight for proper growth and flowering. Any excess shade should be removed during the summer months (March–April) in newly planted areas, and after the summer showers (May–June) for an

existing plantation. It is desirable to maintain a mixed population of medium-sized shade trees that facilitate shade regulation and to maintain more or less optimum conditions throughout the year. Balangi (*Artocarpus fraxinifolius* Wt), Nili (*Bisochofia javanica* Blum), Jack (*Artocarpus heterophyllus* Lamk), Red cedar (*Cedrela toona* Roxb), Karimaram (*Diospyros ebenum* Koenig), Karna (*Vernonia monocis* C.B. Darke), Nandi (*Lagerstroemia lanceolata*) and Spanish cherry (*Mimusops elengi*) are desirable as shade trees for cardamom (Rai, 1978). George *et al.* (1984) reported 40–50 % higher cardamom yield under *Diospyros ebenum* than under Jack, Nandi and Spanish cherry.

The desirable characteristics of shade trees are leguminous species, defoliation during the rainy season, self-pruning habit and flowering during summer. Most shade trees shed leaves between September and December; highest leaf shed was noticed in *Syzygium cumini* followed by *Terminalia arjuna*. As far as major nutrients are concerned, *Erythrina indica* recorded higher contents of nitrogen and phosphorous, while *Lagerstroemia lanceolata* contained more potassium (Dinesh Kumar and Babitha, 2006).

The survey and economic analysis of various cardamom plantations adopting mixed cropping systems in Kerala and Karnataka indicated that the inclusion of black pepper, coffee and areca nut was highly remunerative, giving higher cost–benefit ratios (Srinivasan *et al.*, 1999). Mixed cropping of cardamom in areca nut gardens give a higher income than areca nut monocropping (Korikanthimath *et al.*, 1997a,b).

8.5.11 Pollination management

The number of honeybee colonies required for effective pollination of cardamom is a minimum of four colonies (about 5000 foragers per colony) per hectare (3000 plants). Bee pollination resulted in a 9–13 % yield increase and better quality capsules of uniform size and shape. Mulching during flowering hinders bee pollination, resulting in a 33–44 % reduction in fruit set. Thus, de-mulching is recommended after the pre-monsoon showers to facilitate better honeybee movement and capsule setting. Promoting the use of beekeeping for pollination of cash crops will be of benefit to both the beekeeper, who will receive money for the pollination services of his honeybees as well as harvesting more honey, and the farmer whose income will be increased through boosting crop productivity as a result of the pollination services of the bees.

8.5.12 Nutrient management

Cardamom is generally grown in the rich fertile soils of the forest ecosystem. Being perennial, steady absorption and utilization of plant nutrients take place throughout the lifecycle of cardamom and hence a regular application of nutrients should be followed for higher yields (Korikanthimath, 1984). Application of compost or farmyard manure, 5 kg/plant/year during May–June, is recommended. Application of 3–4 tonnes of well-rotted cattle or sheep manure apart from 30 kg each of N, P_2O_5 and 40 kg K_2O/acre can greatly enhance the yield (Shanmugavelu and Madhava Rao, 1977). Thimmarayappa *et al.* (2000) reported that integrated nutrient management with 25 % organic manure + 75 % inorganic fertilisers and 50 % organic manure + 50 % inorganic fertilizers recorded yields on a par with 75 % organic manure + 25 %

inorganic fertilizers. Application of the recommended NPK nutrients as organic fertilizers (50 % each as FYM and neem cake + 50 % P each as bone meal and rock phosphate + 50 % K as wood ash) has been shown to be as effective in increasing the yield and quality of cardamom (Sadanandan and Hamza, 2006).

Application of organic manures such as neem cake (1 kg) or poultry manure/FYM compost/vermicompost (2 kg) per plant is recommended once in a year during May–June. Nearly 70 % of cardamom roots are confined to a shallow depth of 5–40 cm and 30–50 cm radius (Khader and Sayed, 1977; Nair, 1988). Therefore, it is necessary to apply the fertiliser at a radius within 50 cm. Being a surface feeder, deep placement of manure is not advisable for cardamom.

Three species of VAM fungi (*Glomus macrocarpum*, *G. fasciculatum* and *Gigaspora coralloidea*) have been recorded in the roots of cardamom plants. Percent colonization in roots varied from 40–100 % in pre-monsoon samples and 63–94 % in post-monsoon samples. Seedlings inoculated with the VAM fungi grew taller and had more leaves and tillers and greater seedling biomass and uptake of nutrients than control seedlings. Among the various mycorrhizal fungi tested, seedlings inoculated with *Gigaspora margarita* and *Glomus monosporum* exhibited significantly greater growth with increased uptake of nutrients.

8.6 Harvesting and post-harvest processing

Cardamom plants start bearing two years after planting. Panicles appear from the base of the plant from January onwards; flowering is between April and December, and may extend further. Peak flowering is observed during June–August and fruits mature in about 120 days after flowering. Fruits have trilocular capsules containing 15–20 seeds and, on maturity, the seeds turn black in colour.

Due to staggered and prolonged flowering, cardamom capsules mature and are ready for harvesting successively at 10–15 day intervals over an extended period of 8 months (August–March). Harvesting is carried out at an interval of 15–30 days and is completed in eight to nine rounds. Fruits (capsules) that are fully matured have a dark green coloured rind (peel) with black coloured seeds, indicating that they are ready for harvesting. Harvesting at an over-ripe stage leads to a loss of the green colouring in the rind, and the capsule is at risk of splitting during curing. Percent recovery of dry capsules varies from 20–24 % in ripe capsules, 18–20 % at the physiologically mature stage and 14–16 % at the immature stage. Hence, it is ideal to harvest cardamom at the physiologically mature stage (green coloured rind and black coloured seeds) (Leela *et al.*, 2008). After harvesting, the capsules are cleaned and cured to reduce the moisture content from 80 % to 8–12 % in an optimum environment for retaining green colour to the maximum extent.

The colour of processed cardamom is an important factor in the consumer market. Different chemical treatments have been tried to retain the green colour of harvested capsules because such a product fetches premium price in the market. Soaking green capsules immediately after harvest in 2 % sodium carbonate solution for 10 minutes results in retention of the green colour during subsequent drying and storage (Natarajan *et al.*, 1968). Immature capsules also retain greater intensity of green colour.

8.6.1 Curing

On maturity, the dark green capsules are harvested and dried within 24–36 hours, in order to avoid quality deterioration. Cardamom curing is the process in which the moisture content of freshly harvested cardamom capsules is reduced from 70–80 to 11–12 % at an optimum temperature of 45–55 °C to retain its maximum green colour and volatile oil (Pruthi, 1993). The widely adopted system is a slow, passive process stretching up to 24–30 hours with an initial temperature around 45 °C.

Maturity of capsules and curing temperature influence the colour and quality of processed (cured) cardamom. During the process of curing, if temperature exceeds the threshold levels, capsules tend to develop brownish streaks as a result of heat injury. High temperature also results in volatile oil loss from seeds. Maintaining an optimum temperature of 40–45 °C in all the four stages of curing helps in retention of green colour. Curing at a temperature of 55 °C and 60 °C significantly increases the percentage of yellow and split capsules. The husk of raw capsules contains about 8 % water, which has to be removed completely during the process of drying. Maximum loss of chlorophyll occurs in the initial 6 hours of curing, and hence a lower temperature is maintained in the initial stages. Some established drying methods for cardamom are described below.

Natural (sun drying)

The capsules are dried directly in sunlight for a period of 5–6 days or more, depending upon availability of the sunlight. Frequent turning of the capsules is required during drying, which can lead to splitting. Cloudy weather and frequent rain during drying hinder the process. This method is commonly used in Karnataka (Vadiraj, 2004). The sun-dried capsules are not preferred for the export market.

Flue pipe dryer (kiln drying)

Kiln drying is one of the best methods of drying to obtain high-quality green cardamom. These curing houses are masonry structures, which are fabricated to meet the requirements. The dryer structure consists of walls which are made of brick or stone with a tiled roof. A furnace is on one side of the chamber and the heat energy is generated by burning firewood. The heated air current is passed on to the drying chamber through a pipe. The fire is regulated to maintain the temperature at 45–55 °C, and by this method quality green cardamom can be obtained in 24–30 hours. A drying chamber of dimension 4.5 × 4.5 m is sufficient for a plantation producing 2 tonnes of fresh cardamom (Kachru and Gupta, 1993). The major disadvantages of this method are the high construction costs and the large quantity of firewood required.

Melccard dryer

A melccard dryer consists of a fully-insulated (bricks with mud coating) oven kept at 3 m below the dryer. The hot flue gas from the oven is passed to an iron tank through insulated pipes. The four iron pipes carry the flue gas from the smoke tank to the dryer. Two chimneys are provided for an exhaust. The surface of the smoke tank and the flue pipes transfer the heat energy to the dryer. A central opening in the ceiling of the dryer (with an exhaust fan) ensures removal of excess heat. Roofing is also insulated with thick glass wool. The dryer can be loaded easily by opening the front doors (Palaniappan, 1986). This is a firewood-operated dryer commonly used in a few places in Tamil Nadu.

8.6.2 Improved curing methods

Research has been undertaken to improve cardamom curing methods. Some alternative techniques are detailed in the paragraphs that follow.

Electrical dryer

Though different types of electrical dryer are available, the one most commonly used has dimensions of 90 × 84 cm. The aluminium trays (81 × 40 cm) for drying can be arranged one above the other with a 2 cm gap in between. Green capsules are uniformly spread on the trays and arranged in the dryer. Uniform distribution of heat is ensured by means of fans. This method results in good green-coloured cardamom when the temperature is maintained between 45 and 50 °C. The major limitations of this method are availability of electricity and high cost. Furthermore, the splitting rate of capsules is high when compared to the conventional system.

Bin dryer

The bin dryer was designed by the University of Agricultural Sciences, Bangalore, Karnataka. The drying unit consists of an electrical heating unit and a blower with a motor and drying chamber. The blower is a backward curve vane type connected to a 373 kW motor, with 2820 revolutions per min. The volume of air driven through the dryer can be adjusted to 1.5–8 cm^3/sec. The dryer is made of mild steel, asbestos sheet and wood. Aluminium or steel trays, 0.4 × 0.6 m, can be arranged one above the other, with the cardamom capsules uniformly spread on them. The required amount of hot air is circulated around the trays by means of a centrally located flue pipe. Good-quality cardamom can be produced by drying the capsules at 55 °C by maintaining the volume of air at 3.7 m^3/s (Gurumurthy *et al.*, 1985).

Solar cardamom dryer

The direct type solar dryer developed by the Central Plantation Crops Research Institute, Kasargod, Kerala, for coconut can also be used for cardamom. The drier has an area of 1 m^2 drying surface comprising a wire mesh tray placed over a corrugated GI sheet inclined at 12.5°. Aluminum foil reflectors of 1.5 m^2 are provided from three sides of the drier. Material load density can be three times more than that used in an open drying system. Complete drying of cardamom can be achieved within 3 days using this dryer in comparison to 5 days under the open sun.

Mechanical cardamom dryer

This drier was developed by the Regional Research Laboratory, Trivandrum, Kerala and consists of a centrifugal blower, an electric furnace, uniform hot air flow and a drying chamber. It can be used for drying 120 kg of fresh cardamom per batch. It takes 22 hours for complete drying at a temperature of 50 °C. The final product is superior in green colour, flavour and appearance (Kachru and Gupta, 1993).

Other types of improved driers include the kerosene stove dryer, the liquefied petroleum gas (LPG)-based dryer and the diesel dryer (Vadiraj *et al.*, 2002).

8.6.3 Bleaching of cardamom

Bleached cardamom is creamy white or golden yellow in colour. Bleaching can be done either with freshly harvested capsules or with dried cardamom capsules. The

fresh capsules are soaked in 20 % potassium metabisulfite solution containing 1 % hydrogen peroxide for 1 hour to degrade the chlorophyll. Drying of these capsules yields golden yellow coloured bleached cardamom.

Sulphur bleaching of dry capsules

This process involves fumigation using sulphur with alternate periods of soaking and drying. Capsules are soaked in 2 % bleaching powder (20 g/l of water) for 1 hour and spread on wooden trays which are arranged inside air-tight chambers. Sulphur dioxide (SO_2) is produced by burning sulphur (15 g/kg of capsules) which is passed over the trays. The process of soaking and drying is repeated three to four times depending on the intensity of white colour required.

Potassium metabisulphite bleaching

In this method, capsules are treated with 2 % potassium metabisulphite containing 1 % hydrogen Chlonide (HCl) for 30 minutes. Following this, they are transferred to a 4 % hydrogen peroxide (H_2O_2) solution for 6 hours.

Hydrogen peroxide (H_2O_2) bleaching of dry capsules

H_2O_2 at a low concentration (4–6 %, pH 4) can bleach capsules in 6–8 hours of soaking. These capsules are then dried to a moisture content of 10–12 %. Bleached capsules contain sulphur which protects cardamom from pests. However, bleaching also results in loss of volatile oil.

8.6.4 Packaging

Cardamom is a high-value spice and all care should be given to efficient packing. The cured capsules are graded using sieves of 8, 7.5, 7 and 6 mm which are manually operated. After grading, cardamom needs to be stored over a period of time; it is normally kept in double-lined polythene bags. Storage rooms should be free from insect damage. Studies have shown that drying cardamom and maintaining it at or below 10 % moisture helps to retain the original parrot green colour without mould growth (Govindarajan *et al.*, 1982). It is advisable to make use of dried cardamom capsules preferably within 12 months of harvesting.

8.7 Other value-added products from cardamom

8.7.1 Cardamom seeds

Cardamom seeds are obtained by decorticating the capsules. Decortication is achieved using a flourmill or plate mill, also known as a disc mill. Normally the ratio of seeds to husk is 70:30.

8.7.2 Cardamom powder

Cardamom in its powder form gives the maximum flavour to the food products, but the disadvantage with powder is that it loses aroma quality by rapid loss of volatiles. Hence, the powder needs more protection than whole capsules or seeds. Koller

(1976) found that vacuum-packed ground cardamom stored at 5 C retained flavour for long periods.

8.7.3 Cardamom oleoresin

Oleoresin is made of two components, *viz.*, the volatile oil and the resin. Volatile oil represents the aroma while the resin is made up of non-volatile matter, such as colour, fat, pungent constituents, waxes, etc. The total flavour effect of a spice is obtained only after blending the oil and resin. Volatile oil is obtained by steam or hydrodistillation while the resin is obtained by solvent extraction. The demand for cardamom oleoresin is slowly increasing, probably due to its mellower and less harsh flavour characteristics (Sankarikutty *et al.*, 1982). Sensory differences have also been noted between cardamom oleoresin and cardamom oil (Govindarajan *et al.*, 1982)

8.7.4 Cardamom oil

Cardamom oil is obtained by distillation of powdered seeds of cardamom. Steam distillation is the common method employed for the production of oil. The quality of the oil depends on the variety, rate and time of distillation. Volatile oil yield from seeds of Alleppey green, Coorg green and Saklesphpur bleached was 10.8, 9.0 and 8.0 %, respectively (Lewis *et al.*, 1966). High-grade cardamom is not economical for distillation, since it fetches a better price as whole cardamom in the trade. Lower grades which do not fetch a higher value when sold whole are ideally suited for distillation. The husk is almost devoid of any volatile oil. The flavour of cardamom is mainly due to 1,8-cineole, terpinyl acetate, linalyl acetate and linalool (Lawrence, 1978).

8.7.5 Extraction techniques

The oil is isolated either by the traditional hydrodistillation or by steam distillation. The major disadvantages of these methods are the loss of volatile components, longer periods of extraction and thermal or hydrolytic degradation of unsaturated or ester compounds (Tuan and Hangantileke, 1977; Khajeh *et al.*, 2004). A steam-distilled essential oil of cardamom was characterised by a high proportion of monoterpenes (87.6 %). The main monoterpene was 1,8-cineole (35.6 %) followed by α-terpenyl acetate (27.1 %), α-terpineol (4.9 %), linalool (4.1 %) and thujyl alcohol (Kaskoos *et al.*, 2006).

The volatile oil composition of cardamom seeds using supercritical CO_2 extraction shows the main components as follows: α-terpinyl acetate, 42.3 %; 1,8-cineole, 21.4 %; linalyl acetate, 8.2 %; limonene, 5.6 %; and linalool, 5.4 %. The extract obtained using hexane shows strong compositional differences, mainly of the following: limonene, 36.4 %; 1,8-cineole, 23.5 %; terpinolene, 8.6 %; and myrcene, 6.6 % (Marongiu *et al.*, 2004). A comparison with the hydrodistilled oil obtained at a yield of 5.0 %, did not reveal any consistent difference.

Recent methods for extraction of natural products using microwave energy, i.e, solvent free microwave extraction (SFME) and also using supercritical CO_2

extraction have been successfully employed in the case of cardamom (Lucchesi *et al.*, 2007). SFME is based on the combination of microwave heating and distillation and is performed at atmospheric pressure. The composition of extracted oil varies with time, moisture content and irradiation power. The extraction time must be optimised to maximise the yield of the extraction without affecting the quality of the oil. When utilising microwave treatment, moisture content is critical since water is an excellent absorber of microwave energy. This energy subsequently provides a rise in temperature and ruptures the essential oil cells through the *in situ* water. Irradiation power is directly related to the sample size. The power must be sufficient to reach the boiling point of water (100 °C).

Six major compounds of the cardamom essential oil have been identified, namely: 1,8-cineole, α-terpinyl acetate, linalool, linalyl acetate, α-terpineol and terpin-4-ol, in order of importance. These six compounds represent almost 90 % of the aromatic compounds of the essential oil from cardamom and all of them are oxygenated compounds. A comparison of the SFME method and hydrodistillation indicated the difference in the yields of the two major aromatic components *viz*; 1,8-cineole and α-terpinyl acetate (Lucchesi *et al.*, 2007). Hydrodistillation is characterized by a long extraction time (six hours) and a high humidity level (~99 %). Overall, 1,8-cineole fraction seems to decrease with time, power and moisture, whereas α-terpinyl acetate seems to increase.

Monoterpene hydrocarbons are less valuable than oxygenated compounds in terms of their contribution to the fragrance of the essential oil. In the case of SFME, substantially higher amounts of oxygenated compounds are seen, when compared with hydrodistillation. This is probably due to the diminution of thermal and hydrolytic effects during SFME, compared with hydrodistillation. The more polar the compounds, the more readily microwave irradiation is absorbed with better interaction between wave and matter, resulting in higher aromatic components. This corresponds with the higher levels of 1,8-cineole, which is more polar than α-terpinyl acetate.

Grinding is a very important step in the processing of cardamom as it involves the additional problem of volatility and loss of the aroma-giving essential oil present within it, which is the sole criterion of quality for this spice. Low-temperature grinding is the practical way to achieve fine grinding without loss of flavour principles. The process of cold grinding (2–5 °C) enhances the volatile oil content and the quality of the oil in terms of its aroma constituents (Omanakutty and Joy, 2007).

Marongiu *et al.* (2004) studied the effect of supercritical CO_2 extraction (SC-CO_2) conditions on the yield and composition of the resulting cardamom volatile oil by testing two pressure values, 9.0 and 11.0 MPa; two temperatures, 40 and 50 °C; two flow rate values, 0.6 and 1.2 kg/h; and two particles size values, 250–425 and >850 μm. The extraction conditions that gave the highest yield, Y (grams of extract per gram of seeds), of 5.5 %, were as follows: pressure, 9.0 MPa; temperature, 40 °C; CO_2 flow, ϕ = 1.2 kg/h; and particles sizes in the range of 250–425 μm. Waxes, recovered as traces, were entrapped in the first separator set at 9.0 MPa and –10 °C. The oil was recovered in the second separator working at 1.5 MPa and 10 °C. The main components were α-terpinyl acetate, 42.3 %; 1,8-cineole, 21.4 %; linalyl acetate, 8.2 %; limonene, 5.6 %; and linalool, 5.4 %.

8.7.6 Storage

Quality parameters of cardamom oil obtained by supercritical CO_2 extraction and stored at 0 °C or at ambient temperature (28 ± 3°) have been compared with those of commercially steam-distilled oils at ambient temperature (Gopalakrishnan, 1994). α-Pinene, sabinene and limonene are the major terpene hydrocarbons which undergo remarkable changes during storage. These hydrocarbons show 35–50 % reduction during 90 days of storage at 0 °C, in CO_2 extracted oil. α-Pinene and sabinene together are reduced from 7.1 % to 0.4 % at ambient temperature. Similarly, α-limonene is reduced from 2.3 % to 0.5 % during the same period of storage. The above hydrocarbons are reduced from 14.4 % to 6.8 % in the commercial oil stored at ambient temperature. Cineole content decreases in the 0 °C stored samples, from 27 % to 21.8 %, and in the ambient temperature stored samples, from 27 % to 14.7 %, and from 38.8 % to 27.8 % in commercial oil. Reductions in percentage proportion of these values are, respectively, 19 %, 45 % and 28 %. Changes also take place in the terpene alcohols but are not prominent. In the CO_2 extract distilled oil stored at 0 °C, α-terpinyl acetate content increases during 90 days of storage. In other samples, a remarkable increase of this ester content is noted by 45 days. The two minor esters, geranyl acetate and linalyl acetate, also undergo minor changes in their contents in all of the samples during storage.

8.7.7 Effect of γ-irradiation in volatile oil composition

γ-Irradiation is currently used for the decontamination of spices, but its effect on essential oil composition is controversial and contradictory in cardamom (Ljubica *et al.*, 1983; Klaus and Wilhelm, 1990; Maija *et al.*, 1990). The parent yield of volatile essential oil isolated from non-irradiated (NI) and irradiated (I) samples of cardamom do not reveal any significant difference. Gas–liquid chromatography (GLC) profiles of the two samples of non-irradiated and irradiated oil do not show any variation in the retention time, but the relative percent distribution of the major constituents in the oil exhibits clearcut quantitative differences (Variyar *et al.*, 1998).

8.7.8 Encapsulation

The cardamom flavour is incorporated in processed foods, mainly by using the hydrodistilled cardamom oil or the solvent-extracted cardamom oleoresin (Govindarajan *et al.*, 1982). Solvent extraction of ground seeds of cardamom gives a greenish oleoresin containing about 70 % volatile oil. It has the full flavour of the spice. At an elevated temperature, changes may occur in the volatile oil constituents. Cardamom volatile oils consist of terpenoids, which are generally unstable under detrimental conditions like acid, light, oxygen or heat. There is an increase in *p*-cymene, a terpene with petroleum-like aroma, at the expense of the major constituent, α-terpinyl acetate, which contributes to the desirable flavour of this spice (Brennand and Heinz, 1970). These problems are overcome by microencapsulation, which is defined as the technique of packing minute particles of a core material within a continuous polymer film that is designed to release its contents in a predictable manner under a predetermined set of conditions (Beristain *et al.*, 2001). Microencapsulation of cardamom oleoresin using gum Arabic could entrap the aroma for

six weeks (Krishnan *et al.*, 2005). This technique will be highly useful in the preparation of many pastry products that utilize cardamom at higher oven temperatures (from 149–205 °C) and beverages at lower ranges of pH.

8.8 Chemical structure and characteristics

8.8.1 Volatiles

The volatile oil components in cardamom are summarised by Guenther (1975). The first detailed analysis of the oil was reported by Nigam *et al.* (1965). The oil has few mono- or sesquiterpenic hydrocarbons and is dominated by oxygenated compounds, all of which are potential aroma compounds. While many of the identified compounds (alcohols, esters and aldehydes) are commonly found in many spice oils (or even volatiles of many different foods), the dominance of the ether, 1,8-cineole, and the esters, -terpinyl and linalyl acetates, in the composition, makes the cardamom volatiles a unique combination (Lewis *et al.*, 1966; Salzer, 1975; Korikanthimath *et al.*, 1997c). The major components in cardamom oil are given in Table 8.4, while the trace components are grouped in Table 8.5.

The volatile oil, the most functionally important constituent of cardamom, varies in level from 6.6–10.6 % in seeds for cv. *Mysore* and *Malabar* grown in India (Krishnamurthy, 1964; Krishnamurthy *et al.*, 1967; Korikanthimath *et al.*, 1999). The oil content is low in the immature capsules (in the order of 4–5 %), while the husk oil level is reported to be 0.2 %, the husk oil being reported as having similar properties to the seed oil (Rao *et al.*, 1925). Large differences can be found between the

Table 8.4 Main components of volatile oil in small cardamom

Components	Total oil
α-Pinene	1.5
β-Pinene	0.2
Sabinene	2.8
Myrcene	1.6
α-Phellandrene	0.2
Limonene	11.6
1,8-cineole	36.3
γ-Terpinene	0.7
p-Cymene	0.1
Terpinolene	0.5
Linalool	3.0
Linalyl acetate	2.5
Terpinen-4-ol	0.9
α-Terpineol	2.6
α-Terpinyl acetate	31.3
Citronellol	0.3
Nerol	0.5
Geraniol	0.5
Methyl eugenol	0.2
trans-nerolidol	2.7

Sources: Lawrence (1978); Govindarajan *et al.* (1982).

Table 8.5 Trace components in cardamom volatile oil

Hydrocarbons	Acids	Carbonyls
α-Thujene	Acetic	3-methyl butanal
Camphene	Propionic	2-methyl butanal
α-Terpinene	Butyric	Pentanal
cis-ocimene	2-methyl butyric	Furfural
trans-ocimene	3-methyl butyric	8-acetoxy carvotanacetone
Toluene	Alcohols and phenols	Cuminaldehyde
p-Dimethylstyrene	3-methyl butanol	Carvone
Cyclosativene	*p*-methyl-3-en-l-ol	Pinole
α-Copaene	Perillyl alcohol	Terpinene-4-yl-acetate
α-Ylangene	Cuminyl alcohol	α-Terpinyl propionate
γ-Cadinene	*p*-cresol	Dihydro-α-terpinyl acetate
Δ-Cadinene	Thymol	

Sources: Lawrence (1978); Govindarajan *et al.* (1982).

Table 8.6 Concentration of 1,8-cineole and α-terpinyl acetate in cardamom oils from different origins

S. No	Oil kind	Percentage	
		1,8-cineole	α-Terpinyl acetate
1.	Guatemala I	36.40	31.80
2.	Guatemala II	38.00	38.40
3.	Guatemalayan *Malabar* type	23.40	50.70
4.	Guatemalayan I	39.08	40.26
5.	Guatemalayan II	35.36	41.03
6.	Synthite (Commercial grade)	46.91	36.79
7.	Mysore type (Ceylon)	44.00	37.00
8.	Malabar type (Ceylon)	31.00	52.50
9.	Mysore I	49.50	30.60
10.	Mysore II	41.70	45.90
11.	Mysore	41.00	30.00
12.	Malabar I	28.00	45.50
13.	Malabar II	43.50	45.10
14.	Ceylon type	36.00	30.00
15.	Alleppy I	38.80	33.30
16.	Alleppy green	26.50	34.50
17.	Coorg green	41.00	30.00
18.	Mangalore I	56.10	23.20
19.	Mangalore II	51.20	35.60
20.	Papua New Guinea	63.03	29.09
21.	Cardamom oil (India origin)	36.30	31.30

Source: Govindarajan *et al.* (1982).

concentrations of 1,8-cineole in the oils of var. *Malabar* and var. *Mysore*. In var. *Mysore*, linalool and linalyl acetate are markedly higher. This, along with a low content of 1,8-cineole, makes var. *Mysore* the largest selling Indian cardamom grade, Alleppey Green (Table 8.6). Variability in the in the oil content and the composition of the two main components (1,8-cineole and α-terpinyl acetate) in the

germplasm collections at Indian Institute of Spices Research – Cardamom Research Centre, Karnataka are as indicated in Table 8.7.

The aroma differences in different sources of cardamom are attributed to the proportion of the esters and 1,8-cineole (Wijesekera and Jayawardena, 1973; Korikantimath *et al.*, 1999). The flavour characteristics of some important volatile components of cardamom are given in Table 8.8 and the chemical structures in Fig. 8.2.

8.8.2 Variability in oil composition

The value of cardamom as a food and beverage additive depends on the aroma components in the volatile oil. These are subject to variation according to variety, maturity, processing, extraction techniques and storage.

Table 8.7 Chemical quality profile of cardamom germplasm at Indian Institute of Spices Research, Calicut, Kerala

Acc. No.	Essential oil (%)	1,8-cineole (% of oil)	α-Terpinyl acetate (% of oil)
APG7	5.5	51	29
″12	8.6	37	43
″20	9.4	48	34
″23	9.4	39	39
″25	7.5	38	43
″27	6.9	34	33
″32	5.6	38	44
″44	7.1	34	38
″48	6.3	41	33
″54	6.8	44	34
″65	7.5	32	45
″69	8.3	49	28
″71	7.3	36	31
″87	5.7	42	32
″98	6.3	33	30
″106	10.0	43	39
″112	6.6	45	34
″117	6.3	38	43
″134	6.0	40	38
″135	9.9	45	40
″158	6.6	40	38
″175	9.8	43	40
″178	5.6	22	39
″180	6.8	31	32
″183	7.8	24	39
″187	8.0	22	48
″193	8.3	28	47
″215	6.0	23	55
″217	6.0	25	51
″218	7.8	24	52
″221	7.8	37	40
CCS-1	8.6	42	36

Source: Zachariah and Lukose (1992).

Table 8.8 Flavour characteristics of important volatile components in cardamom

Components	Flavour description	Flavour effect and use	Use level concentration (%)	Range of cardamom oil
Esters				
α-Terpinyl acetate	Mildly herbaceous, sweet spicy, Variation in odour, warm, mild spicy taste.	To stretch cardamom, herbal spice, imitation of citrus, cherry and peach flavours.	1–15 ppm	34.6–52.5
Linalyl acetate	Sweet, floral, fruity odour and taste, poor tenacity, but stronger than terpinyl acetate.	Fresh, sweet modifier in perfume and berry flavours.	2–15 ppm	0.7–6.3
Ethers				
1,8-cineole	Fresh, camphoraceous, cool odour and taste, very diffusive and poor tenacity.	Refreshing effect and lift; extensively used in perfume and flavours.	1–15 ppm	23–51
Alcohol linalool	Floral, woody with citrus note; creamy floral taste at low levels.	Lift to heavy perfume; peculiar pleasant taste effect at low levels.	2–10 ppm	1.4–4.5
μ-Terpineol	Delicately floral, sweet, lilac like.	Citrus and spice compositions.	5–40 ppm	1.4–3.3
Others				
Methyl eugenol	Musty tea like, mildly spicy, warm, slightly earthy.	Tenacious, dry, herbaceous spicy effect.	5–15 ppm	1.3

Source: Bernhard *et al.* (1971).

Extracts of cardamom cultivated in Costa Rica have been analysed by gas chromatography–mass spectroscopy (GC–MS) on various columns. Among the 122 compounds found, 56 represented over 99 % of the total volatile oil fraction, and 74 % were reported for the first time. Their distribution is similar to that described for other samples of *E. cardamomum* var. minor, grown in other countries (Noleau *et al.*, 1987). Traded (exported) cardamoms from India, Sri Lanka and Guatemala have been characterised based on the physical and biochemical parameters and molecular techniques (Elizabeth *et al.*, 2006). Indian cardamom was found to be superior in terms of most of the physical quality parameters and for the biochemical traits. The GC profile of the oil of Indian cardamom also indicated a high quantity of α-terpinyl acetate and 1,8-cineole which imparts aroma and flavour to the cardamom, thus reinforcing the legendary belief in the high intrinsic quality of the Indian cardamom.

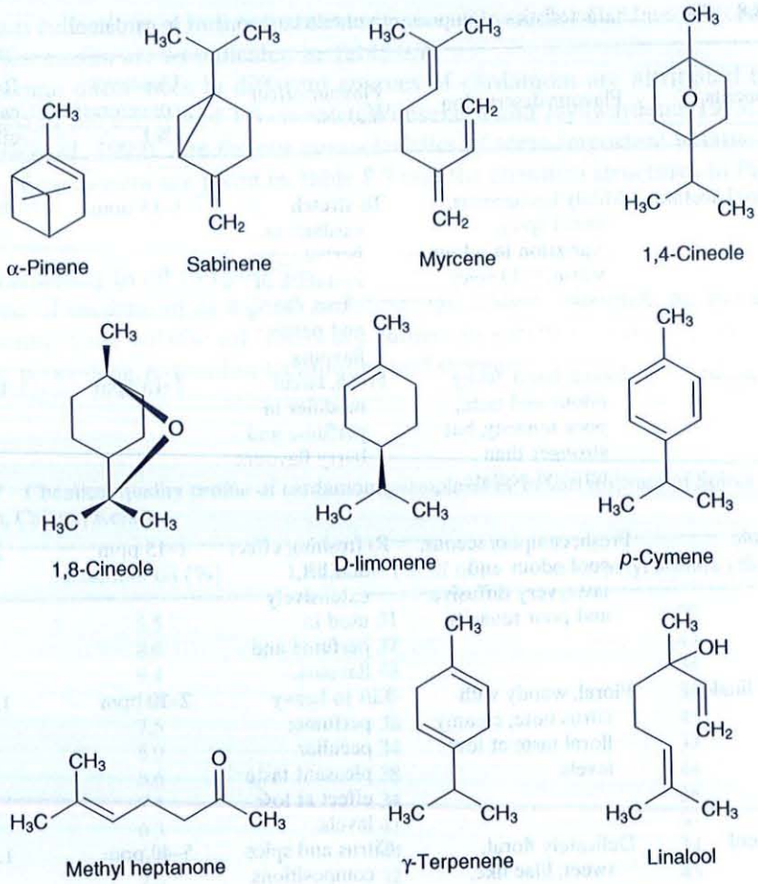

Fig. 8.2 Major essential oil components in small cardamom.

8.9 Major uses of cardamom

8.9.1 Traditional medicinal uses

The major medicinal properties of cardamom essential oil are its antiseptic, carminative, digestive, diuretic, stimulant, stomachic, tonic and antispasmodic, antimicrobial and anti-inflammatory activities (Al-Zuhair *et al.*, 1996; de Pradier, 2006). It is also used as an aphrodisiac; it is helpful in countering the irritation experienced during premenstrual tension; and it works well on the respiratory system to ease coughs and to warm the body. The seeds of cardamom are considered cooling and stimulating and a carminative, stomachic, diuretic, cardiotonic and abortifacient. They have been used to treat bronchitis, haemorrhoids, stangury, renal and vesical calculi, anorexia, dyspepsia and gastropathy (Wanrrier *et al.*, 1994). Powdered cardamom seeds mixed with ground ginger, cloves and caraway have been used mainly for combating digestive ailments. Use of cardamom checks nausea and vomiting.

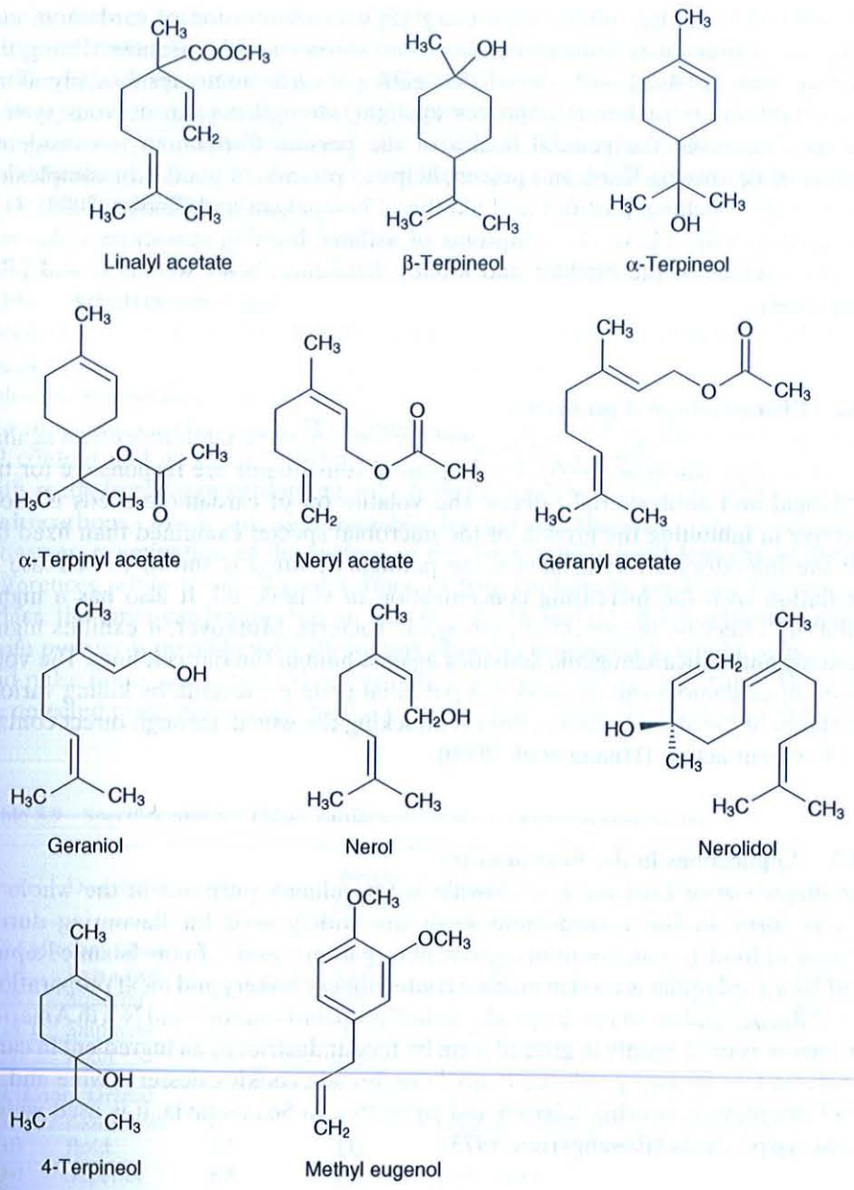

Fig. 8.2 *Continued*

Cardamom seeds can lessen inflammation, as well as being useful for headaches (Govil, 1998). They are chewed to prevent bad breath and to prevent pyrosis (excessive watering in mouth). Powdered seeds of cardamom, boiled with tea-water, impart a very pleasant aroma to the tea, which can be used as medicine for scanty urination, diarrhoea, palpitation of the heart, exhaustion due to overwork

and depression among other things. Gargling with an infusion of cardamom and cinnamon is thought to cure pharyngitis, sore throats and hoarseness, during the infective stage of flu. It is believed that eating a cardamom capsule daily along with a tablespoon of honey improves eyesight, strengthens the nervous system and thus improves the general health of the person. Cardamom is considered capable of destroying Kapa and poison, helps to promote a good skin complexion and to relieve itching, pustules and akotha (Chempakam and Sindhu, 2008). It is also used to help relieve the symptoms of asthma, burning sensations, colds and coughs, diseases of the bladder and kidney, flatulence, heart weakness and piles (Dey, 1994).

8.9.2 Pharmacological properties

Cardamom has antimicrobial activity and the seeds have an inhibitory effect against microbes (Agaoglu *et al.*, 2005). The terpenoid constituents are responsible for the antifungal and antibacterial effects. The volatile oil of cardamom seeds is more effective in inhibiting the growth of the microbial species examined than fixed oil, and the inhibitory effect against some pathogenic fungi is shown to increase in corellation with the increasing concentration of volatile oil. It also has a highly inhibitory effect on the selected pathogenic bacteria. Moreover, it exhibits highly cytotoxic and anticarcinogenic activities against human tumour cell lines. The volatile oil of cardamom can be used as a potential grain protectant, by killing various life stages of the stored product insects attacking the wheat, through direct contact and fumigant action (Huang *et al.*, 2000).

8.9.3 Applications in the food industry

The major use of cardamom worldwide is for culinary purposes in the whole or ground form. In India, cardamom seeds are widely used for flavouring during cooking of food. It is an essential ingredient in 'garam masala'. In the Islamic Republic of Iran, cardamom is used in making confectionery, bakery and meat preparations to add flavour and aroma to the products. In European countries and North America, cardamom is used mainly in ground form by food industries as an ingredient in curry powder, a few sausage products, soups, buns, breads, cookies, desserts, wine and, to small extent, in flavouring tobacco and cigarettes. In Scandinavia, it is used widely in bakery products (Rosengarten, 1973).

8.10 Quality standards and grade specifications

8.10.1 Major specifications

For the most part, grades are based on physical parameters such as colour, size, weight per specific volume and freedom from microbial, insect and filth contaminants. The Bureau of Indian Standards (BIS) and The Directorate of Marketing and Inspection (DMI), Government of India have prescribed fairly well-defined grades for cardamom. The Indian specifications or standards are based on important

quality factors such as colour, weight per unit volume, size and percentage of 'empties', malformed, shrivelled and immature capsules (Tables 8.9–8.13).

The importance attached to the different dimensions of quality varies with the primary producer, the intermediary collector, the trader and exporter, the importer, the processor, the distributor and the consumer. The extraction, volatile oil and ingredients are valued by the processor; the interest of the distributor and consume is in sensory quality and cost.

8.10.2 Adulteration issues

Decorticated seeds can be adulterated with seeds from lower grades, and also with seeds of large cardamom, as they are of similar shape, size and colour. Pale brown coloured seeds can be indicative of immature cardamom, which is poor in quality, low in volatiles and intensity. The seeds from large cardamom have a lower volatile oil content and an entirely different composition and aroma. Gross adulteration with seeds from large cardamom will show higher 1,8-cineole and higher terpene hydrocarbons, which are determinable by gas or thin-layer chromotography. However, examination of the surface of the seeds with a hand lens shows distinct differences, while the seed coat surface of true cardamom has clear furrows and ridges, the large cardamom has an almost smooth surface. Adulteration of cardamom powder is possible with almost any material powdered to similar size. Cereal and pulse flours and extracted ginger have been reported as adulterants. These can be detected using microscopy by the very different size and structure of the starch

Table 8.9 Specifications for Indian cardamom (based on physical characters)

Grade	Description	Size (mm)	Weight (g/l)min	Colour	General characteristics
AG (Alleppey Green)					
AGB	Extra Bold	7	435	Green	Kiln dried, 3 cornered and with ribbed appearance
AGS	Superior	5	385		
AGS 1	Shipment	4	320–350	Light green	
AGL	Light	3.5	260		
CG (Coorg Green)					
CGEB	Extra Bold	8	450	Golden to light green	Round ribbed or smooth skin
CGB	Bold	7.5	435		
CG-1	Superior	6.5	415	Light green	
CG-2	Mota, Green	6	385	Green	
CG-3	Shipment	5.5	350	Cream	
CG-4	Light	3.5	280	Brown	
Bleached					
BL-1		8.5	340	Pale	Fully developed round/3 cornered ribbed or smooth skin
BL-2		7	340	Creamy	
BL-3		5	300	Dull white	

Source: Indian Standard specification for cardamom. IS: 1907–66. Indian Standards Institution, New Delhi-1.

Table 8.10 AGMARK specifications of Coorg clipped and bleachable white cardamoms

Variety	Grade designation	Empty and malformed capsules by count (max) (%)	Unclipped capsules by count (max) (%)	Immature and shrivelled capsules (%) by weight	Size (mm)	Weight g/l (min)
Coorg clipped cardamoms	Bold	5.0	0.0	0.0	8.5	435
	Coorg green or Mota green	5.0	3.0	4.0	6.0	385
	Shipment	3.0	5.0	7.0	4.0	350
	Light				3.5	260
Bleachable white cardamoms	Mysore/Mangalore bleachable cardamom clipped	1.0		0.0	7.0	460
	Mysore/Mangalore bleachable cardamom unclipped	1.0		0.0	7.0	460
	Bleachable bulk cardamom clipped	2.0		0.0	4.3	435
	Bleachable bulk cardamom unclipped	2.0		0.0	4.3	435

Table 8.11 AGMARK specifications of Alleppey and Mangalore cardamom seeds

Variety	Grade designation	Trade name	Extraneous matter (%) by wt.	Light seeds (%) by wt.	Weight (gm/l) min.
Alleppey cardamom seeds	AS1	Prime	1.0	3.0	675
	AS2	Shipment	2.0	5.0	460
	AS3	Brokens	5.0		
Mangalore cardamom seeds	MS1	Prime	1.0	3.0	675
	MS2	Shipment	2.0	5.0	460
	MS3	Brokens	5.0		

Table 8.12 Whole cardamom: chemical and physical specification

Specifications	Suggested limits
ASTA cleanliness specifications	
Whole dead insects, by count	4
Mammalian excreta, by mg/lb	3
Other excreta, by mg/lb	1.0
Mould, % by weight	1.0
Insect defiled, infested, % by weight	1.0
Extraneous, % by weight	0.5
FDA DALs	None
Volatile oil	3 % min.
Moisture	12 % max.
Ash	10 % max.
Acid insoluble ash	2 % max.
Average bulk index (mg/100 g)	
Bleached	320
Green	250

DALs = deficit action levels.

Table 8.13 Ground cardamom: chemical and physical specification

Specifications	Suggested limits
FDA DALs	None
Volatile oil	3 % min.
Moisture	12 % max
Total ash	10 % max
Acid insoluble ash	2 % max
Military specification (EE-S-631J, 1981) (Decorticated Cardamom)	
Volatile oil (ml/100 g)	3 % min.
Moisture	12 % max
Total ash	7 % max
Acid insoluble ash	3 % max
Granulation	95 % min through a USS 40
Bulk index (ml/100 g)	190

granules. Cardamom starch grains, unlike those of cereal and other starches, are very small (2–4 m). Whole cardamom powder can be distinguished from the cardamom seed powder by microsopy. The former can be recognized by the yellowish colour, abundance of pitted fibres, spiral cells of the vascular bundles, empty parenchymatous cells and scattered resin cells with brownish clumps (Melchior and Kastnev, 1974).

8.11 Conclusion

Cardamom is an important spice crop, which has been prominent in world trade since ancient times. Cardamom gained particular popularity during the second half of the twentieth century. Since the 1990s, world cardamom production and demand have increased greatly. Although the aroma and flavour of cardamom are often used in the manufacturing of many foods, consumption in the developed world is low. A concerted effort is required to promote cardamom use in traditional and non-traditional countries.

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