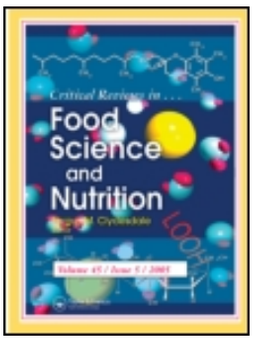

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Postharvest Processing and Benefits of Black Pepper, Coriander, Cinnamon, Fenugreek, and Turmeric Spices

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Spices are prime source for flavor, aroma, and taste in cuisines and play an active role as medicines due to their high antioxidant properties. As medicine or food, the importance of spices cannot be overemphasized. The medicinal values of spices are very well established in treating various ailments like cancer, fever, malaria, stomach offset, nausea, and many more. A spice may be available in several forms: fresh, whole dried, or pre-ground dried which requires further processing to be utilized in the form of value-added product. This review paper deals with the cultivation, postharvesting, chemical composition, uses, health, and medicinal benefits of the selected spice viz., black pepper, coriander, cinnamon, fenugreek, turmeric, and technological advances in processing of spices viz., super critical fluid extraction, cryogenic grinding, and microencapsulation etc. This paper also focuses on issues related to utilization of spices toward its high end-product development and characterization in pharmaceuticals and other medicinal purposes. The availability of different spices and their varietal differences and location have their pertinent characters, which are much demanding to refine postharvest and processing to assure its quality in the international market.

Keywords Spices, postharvest, medicinal benefit, grinding

INTRODUCTION

Man cannot live without food and to make it acceptable to our tongue it is necessary to add taste in it. Hence, spices are inevitable in Indian cooking. According to literature, spice trade was in existence at least 3,500 years ago. Since ancient times, spices and herbs have also been used in traditional treatment, cosmetic, medicine, dye, form of money, and also masked the flavor of meat etc. There are over 80 spices grown in different parts of the world and around 50 spices are grown in India and known by different biological names (Table 1). Spices and herbs are good not only for our taste buds but also for our health. A spice can be defined as the dried aromatic parts of natural plants, whose characteristics such as color and constitution may vary depending on harvest, location, wet or dry conditions, or their historical background etc. Various parts of plants are utilized as spices viz. leaves, barks, buds, fruits etc. Generally, spices composed of fiber, sugar, fat, protein, ash, gum, essential oils, and other component. Spices yields various kinds of aroma and flavor compounds with respect to the amount of essential oil and proportion of each compound contained in it. Spices have various effects besides flavor, pungency, and color, they have antioxidant, antimicrobial, pharmaceutical, and nutritional properties (Table 2). Other secondary effects are salt reduction, sugar reduction, and improved texture for certain foods etc. They supply calcium, iron, vitamin B, vitamin C, carotene, and other antioxidants. The quality of processed spices can also vary due to differences in separation and milling process employed (Table 3). For these reasons, it has been deemed necessary to establish quality standards and specifications for spices. Spices also accounts in the economy by export and import (Table 4).

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Table 1 Different biological names of selected Indian spices

	National (India)				
Language	*Black pepper	Coriander	Cinnamon	Fenugreek	Turmeric
Bangla	Gol Morich	Dhana, Dhania	Darchini	Methi	Hould
Gujarati	Mari, Kalamari, Kalomirch	Kothmiri, Libdhaba		Methi, Methya	Haladar
Hindi	Kali mirch	Dhania, Dhanya	Dalchini, Nagkesar	Methi	Haldi
Kannada	Kalu Menasu	Kothambri, Kothamiri bija	Chakke	Menthya	Arishina
Malayalam	Kurumulagu, Nallamulaku, Yavanapriyam	Kothumpalari bija	Karuvapatta	Uluva	Manjal
Marathi	Kaale Mire, Miri, Ale	Dhana	Dalchini	Methi	Halad
Oriya	Gol Maricha	Dhania	Dalchini	Methi	Haladi
Punjabi	Kaali Mirch	Dhania		Methi	Haldi
Sanskrit	Maricha, ushana, hopusha				
Telugu	Minapappu, Miriyalu	Dhaniyalu	Dalchini chekka	Menthulu/Menti	Pasupu
Tamil	Milagu	Kothamalli	Patthai, Ilavangam, Lavanga pattai, Karuva	Vendayam	Manjal
Urdu	Gol mirch		Dar chini, Dal chini	Methi	
			International		
English	*Black pepper	Coriander	Cinnamon	Fenugreek	Turmeric
Arabic	Babary, Filfil uswad	Kuzhbare	Darasini	Hulba	Kurkum
Chinese	Hu Chiao	Hu-sui		K'u Tou	Yu.Chin
Dutch	Peper	Koriander	Kassia	Fenegriek	Geelwortel
French	Poivre	Corriandre	Cannelle de cochinchine	Fenugrec	Curcuma
German	Pfeffer	Koriander	Z Limtkassie	Bockshorklee	Kurkuma Gelbwurzel
Japanese	Kosha	Koendoro	Bokei	Koroha	Ukon
Portuguese	Pimenta	Coentro		Alforva	Acafrao-da-India
Russian	Pyerets	Koriandr		Pazhitnik	Zholty Imbir
Spanish	Pimienta	Culantro	Canela de la China	Alholva	Curcuma
Swedish	Peppar	Koriander	Kassia	Bockshornklee	Gurkmeja

Source: Gopalan (2002).

This paper reviews the processing and medicinal prospect of selected Indian spices viz. black pepper, coriander, cinnamon, fenugreek, turmeric.

Pepper

Black pepper (*Piper nigrum*), known as the 'king of spices' is a flowering vine and belongs to the family *Piperaceae*. Black pepper is native to India and cultivated in tropical regions. Dried ground pepper is a common spices used for both cuisine and medicinal purpose. Various cultivars are listed in Table 5.

Types

Different types of pepper viz., white pepper, black pepper, green pepper, orange/red pepper and pink pepper are available in trade (Ravindran et al., 2000). Black pepper (Fig. 2a,b,c,d,e) are green unripe drupes of pepper plant (Fig. 1a,b,c) and are cooked briefly in hot water, both to clean and to prepare them for drying. This thermal treatment ruptures the cell walls and catalysis browning enzymes. During drying, seed shrinks and darkens into a thin, wrinkled black layer. Green pepper are dried green peppercorns are treated with sulfur dioxide or freeze-drying to retain the green color. Pickled peppercorns are the unripe drupes (green) preserved in brine or vinegar. These are piquant and fresh flavor with bright aroma. Orange pepper/red pepper is ripened ripe red pepper drupes (Fig. 1d) preserved in brine and vinegar. It can be dried by using the color-preserving techniques viz., sulfur dioxide, freeze-drying etc. Pink pepper (Fig. 2e) are ripened fruits of pepper plant that belongs to different family, *i. e.* Peruvian pepper tree, *Schinus molle*, and native of Brazilian pepper tree, *Schinus terebinthifolius*.

CHEMICAL COMPOSITION

The quality of pepper depends on component viz., piperine (pungency) and volatile oil (aroma and flavor), (Traxler, 1971). The most active compound (Table 6) piperine (1-[5-(1, 3-Benzodioxol-5-yl)-1-oxo-2, 4-petadienyl] piperidine $C_{17}H_{19}NO_3$) (Borges and Pino, 1993) is made up of alkaloids (9%) including piperidine, piperettine, and piperanine. Piperine is tasteless, but its stereoisomer, chavicine, provides its characteristic taste.

Postharvesting/Processing

Harvesting is an important factor in getting high-quality pepper product. Climatic conditions for various spices are

Table 2 Medicinal benefits of different spices

Spices	Benefits
Black pepper	Thermogenic, analgesic, antimicrobial, insecticidal, antipyretic compound. Useful in indigestion, loss of appetite, cold, intestinal worms, bloating, flatulence, toothache, aches, eczema, fevers, tongue injuries, constipation, hemorrhoids excessive thirst, pimples, improving circulation, reducing arthritic pain, boosting immunity, hydrochloric acid secretion, flow of saliva and gastric, strengthen nervous system
Coriander	Analgesic, carminative, digestive, depurative, deodorant, natural antibiotic, antioxidant, antidiabetic, anti-inflammatory galactagogue, antibilious, antispasmodic, aphrodisiac, appetizer, aromatic, diaphoretic, diuretic, refrigerant, stimulant, stomachic, fungicidal, lipolytic, antispasmodic agent. Useful in fever, cold, flu, stomach disorders, digestive problem, diarrhea, mild gastrointestinal upsets, flatulence, colic, dyspepsia, convulsions, insomnia, relief anxiety, reduce cholesterol, laxative remedy, nervous tension, flow of gastric juices, removal of toxins and fluid wastes, stimulate the mind and ease fatigue, mental fatigue, migraine, muscle spasms, arthritis, improves appetite, relieves intestinal cramping
Cinnamon	Anti-clotting, anti-microbial agent, invigorating tonic. Useful in cold, coughs, nausea, vomiting, flatulence, asthma, paralysis, bronchitis, toothache, bad breath, treating diarrhea, indigestion, gas and bloating, stomach upset, gastric ulcers, nervous disorders, loss of appetite, fatigue, hearing loss, dyspepsia, excessive menstruation, uterus disorders, gonorrhea, uterine hemorrhage, menorrhagia, hypertension (high blood pressure), curing minor bacterial and fungal infections of the skin, promoting blood circulation, menopausal symptoms, rheumatic conditions, bacteria, kills fungi, including the molds (aflatoxins), prevents damage to cell membranes by free radical, blood sugar control, boosts brain function, improve colon health and protect against heart disease
Fenugreek	Immunomodulatory, antioxidant, chemopreventive, anticancer, antidiabetic, gastroprotective agent. Useful in hemorrhoids, constipation, fever, chronic coughs, sore throat, boils, mouth ulcers, leg ulcers, chapped lips, eyes/swollen, baldness, piles, vomiting, dropsy, gallbladder problems, abscesses, anemia, asthma, cure leprosy, wound healing, body odor, hair falling, external and internal swellings and burns, eczema, local inflammation, sinus problems astringent to the bowels, myalgia, lymphadenitis, gout, bronchitis, cellulitis, heart burn, production of hormones acid reflux, loss of appetite, dyspepsia, gastritis, atherosclerosis, beriberi, hernia, tuberculosis, enlargement of the liver and the spleen, high serum cholesterol and triglycerides, heart disease, promoting lactation, kidney ailments, lung Infections
Turmeric	Antioxidant, anti-inflammatory, antimutagenic, anticoagulant, anticancerous, chemopreventive, bioprotectant, antiviral, antimicrobial, antiprotozoan, antiparasitic, anti-proliferation, anti-invasion, and anti-angiogenesis, antispasmodic agent. Useful in cuts and burns, promote healing, fevers, cough, cold, mucus in the throat, watery discharges like leucorrhea, any pus in the eyes, ears, or in wounds, dental problems, urinary disorders, diarrhea, ulcers, insanity, lactation problems, poisoning, conjunctivitis gastrointestinal upsets, colic, arthritis pain, low energy, menstrual, abdominal problems. Dispel worms, strengthen the body, dissolve gallstones, decreases congestion, inflammation from stagnant mucous membranes, purifies blood, expels gas from the intestines (as a carminative agent), Colitis, Crohn's disease, post-giardia or post salmonella condition, respiratory disease, dermatophytosis protects lungs and liver from pollution, toxins and pathogens, rebuild the liver after being attacked by hepatoxins, regulate the female reproductive system, purifies the uterus and breastmilk, in men purifies and builds semen, prevents the blockage of arteries, formalin-induced arthritis, reduces intestinal gas formation and carbon tetrachloride and D-galactosamine-induced glutamate oxaloacetate transaminase, glutamate pyruvate transaminase levels, shows antitumor, anticarcinogenic activities, reduces inflammation in arthritis, wound healing

provided in Table 7. Generally, harvesting of pepper spike is done when the berries start to turn yellow/orange in color and firm in texture. The harvesting time for different products of pepper is given in Table 8. Harvested spikes is carried out during the kept in bags (12–24 h) or heaped and covered overnight for a brief fermentation which makes despiking easy. Threshing/Decorning is the removal of spikes from berries by hand, beating with sticks or trampling (Fig. 3). Cleaning is the process of removal of dust, dirt, and stones by manual/mechanical means followed by washing with water for

Table 3 Quality standards of selected spices

	Cleanliness specifications					
	Percentage weight basis (mg/100 g)					
Spice	Dead insects (count)	Excreta, Mammalian	Excreta, Other	Mold	Insect Defiled/Infested	Extraneous/Foreign Matter
Black Pepper	2	0.002	0.011	a	a	1.00
White Pepper	2	0.002	0.002	a	a	0.50
Cinnamon	2	0.002	0.004	1.00	1.00	0.50
Coriander	4	0.006	0.022	1.00	1.00	0.50
Turmeric	3	0.011	0.011	3.00	2.50	0.50

a1% moldy and/or infested pieces by weight.

Table 4 Status of export and import of selected spices from India

	2005–06		2006–07		2007–08		2008–09		2009–10	
Spice	*Q*	*V*	*Q*	*V*	*Q*	*V*	*Q*	*V*	*Q*	*V*
					Export					
Pepper	17,363	15,095	28,750	30,620	35,000	51,950	25,250	41374	19,750	31,392
Coriander	23,756	6771	20,500	7462	26,000	11,025	30,200	20379	47,250	22,586
Fenugreek	15,525	3403	8500	2698	11,100	3300	20,750	7175	21,000	6972
Turmeric	46,405	15,286	51,500	16,480	49,250	15,700	52,500	24858	50,750	38,123
					Import					
Pepper	16,870	10,358.39	15,701	13,597.20	13,500	19388.75	10,750	17664.75	—	—
Coriander	1838	813.81	2270	1008.21	1000	620.00	3030	1906.90	—	—
Turmeric	4022	1676.14	7003	2519.82	4650	1227.30	2,525	820.25	—	—

Source: http://www.indianspices.com/html/s0420sts.htm (Quantity (*Q*) in tonnes, Value (*V*) in lakhs).

two or three times. Sometimes, even immature pepper may receive higher price than matured ones from food processors owing to its higher percentage of flavor components. The cultivars are classified into groups, based on the berry size (Table 9). Blanching (80°C, 2 min) is done before drying to accelerate the drying process and browning of berries to attain black shine color (Pruthi, 1992). Blanching improves color and also removes dust and adhering microbial contamination and also reported its volatiles and other chemical loss are minimum by this method (NRCS, 1987). Blanching activate the phenolase enzyme (responsible for producing black color). It ruptures the cells and accelerates the escape of moisture from inner core and simultaneously enhances the black color with the help of resinoids pressure on the berry. Drying is an important process to reduce the mold growth. Care should be taken to prevent over drying to avoid loss of flavor components. Generally, final moisture content of pepper should be less than 10% wb. The black color that pepper acquires on drying is due to the oxidation of colorless phenolic compounds present in the skin. Polyphenolase (0-diphenol oxidase) present in the fruit wall converts these colorless phenolic substrates (3, 4 dihydroxy phenyl ethanol glycoside) present in the cells to black polymeric compounds (Variyar et al., 1988). The fresh and dry yield depends on temperature and humidity during flowering, soil moisture, fertilizer availability, standards, rainfall etc., (Govindarajan, 1979). To get a good quality product, it is essential to use proper drying surface. The common surfaces used for dying are bamboo mat, cement floor, and polyethylene fabric. Generally, grading is based on size, color, and relative density. Efficient and proper packaging/storage is essential because pepper is hygroscopic in nature and its starch content result in mold attack and insect infestation. It requires optimal conditions of low temperature, low humidity, free from pests and dry place. Whole pepper is packed in gunny bags and polyethylene-lined double burlap bags. Dried pepper (10–11%/wb) is stored in jute gunny bags with polyethylene lining (>0.003 inch) or in laminated bags or similar containers (Balasubramanyam et al., 1978). Polypropylene is generally used for packing of ground pepper.

Value-added Products

Seeds (Green Pepper)

*(i) Dehydrated***:** Immatured green pepper fruits are blanched (80°C, 2 min), drained, cooled, and then soaked in sulphur dioxide solution to fix the green color followed by drying at 50°C. (ii) *Canned***:** Despiked pepper fruits are soaked in water containing 20 ppm residual chlorine for one hour and covered with 2% hot brine solution (0.2% citric acid), was exhausted at 80°C, and sealed. It is cooled immediately in a stream of running cold water and then 2% acetic acid is added to give a better color. Pepper harvested at least one month prior to its maturity is the best for canned green pepper. *(iii) Bottled:* Despiked, clean, fresh green fruits are steeped in 20% brine solution containing citric acid (3–4 weeks). The excess liquid is drained off and fresh brine of 16% concentration together with 100 ppm sulphur dioxide and 0.2% citric acid is added and the product is stored properly. (iv) *Dry packed***:** This product is prepared just like the bottled green pepper except that the liquid at the final stage is drained off and packed in flexible pouches. *Freeze-dried pepper:* This pepper retains the original green color and shape. *White Pepper:* It is prepared by removing the outer rind of the black pepper and is sometimes used in dishes (light-colored sauces or mashed potatoes), where ground black pepper would visibly stand out. They have differing flavor due to the presence of certain compounds in the outer fruit layer of the berry that are not found in the seed. *Black and white pepper powder* (Fig. 2f and g) Ground pepper is obtained by grinding (hammer mill or plate mill etc.) pepper, without adding any foreign matter to it. *Cryoground pepper:* This is obtained by grinding the pepper below −100°C which will prevent the oxidation of oil. *Pepper Oil:* Pepper oil is recovered by steam or water distillation. *Oleoresin:* Oleoresin represents the total pungency and flavor constituents of pepper obtained from ground pepper extraction using solvents like ethanol, acetone, ethylene, dichloride, ethyl acetate etc.

Table 5 Different cultivars of selected Indian spices

Spices	Cultivars	
	Indian	International
Black pepper	Aimpirian,arakulamunda,balankotta,cheppukulamundi, cheriyakaniakkadan,cholamundi,chumala,doddigae,jeerakamundi, karimunda,karimkotta,karimundi,karivilanchi,kurimalai, kuriyalmundi,kalluvally,kottanadan,kuthiravally,mundi,malamundi, malligesara,narayakodi,neelamundi,nedumchola,perambramunda, poonjaranmunda,thulamundi,thevanmundi,thommankodi, uddaghere,uthirankottavadakkan,valiakaniakkadan,vattamundi, vellanamban,Panniyur1, velliyaranmunda, Panniyur 6, Panniyur 2, Panniyur 7, Panniyur 3,	Brazil: Kuching (Singapura), Panniyuri 1 Indonesia: Bangka, Banjarmasin, Belantung, BengKayang, Chunuk, Chunuk Kernuga (CK2), Djambi, Duantebei, Kerenci, Kernuga (CK1), Korintji, LDK (Lampung Daun Kocil), LDL (Lampung Daun Lebar), Palulauta, Petaling 1, Petaling 2, Merefin, Natar 1, Natar 2, LDLN1 (Lampung Daun Lebar Namang 1), LDLN2 (Lampung Daun Lebar Namang 2) Malaysia: Kuching, Sarikei, Miri Sri Lanka: Ceylon, Madagascar, Sel.IV.1 & 2 Thailand: Antique (Buffaloes Horning), Ban keow, Prang Thi, Prang Thi Bai yick, 'thick leaf'.
Coriander	RCr-446, DWA-3, Hisar Anand, Hisar Sugandh, Hisar Surabhi, Azad Dhania-1, Rajendra Swati, Pant Haritima, Co.3, Co.2, Co.1, Co(CR) 4, Guj.Cor.2, Guj. Cor.1, NRCSS-ACr 1, Sadhana, Sindhu, Swathi, RCr.41, RCr 684, RCr 436, RCr 435, RCr 20, Indian summer, slowbolt, spicy asian, nova.	—
Cinnamon	Sugandhini, PPI (C)-1, YCD.1, Navashree, Nithyashree, Konkan Tej.	Cassia or Chinese cinnamon: *C. aromaticum* Korintje or Indonesian cinnamon: *C. burmannii* Saigon or Vietnamese cinnamon: *C. loureiroi* Sri Lanka: Panni Miris Kurundu, Thitta Kurundu, Kahata Kurundu, Veli Kurundu, Sevel Kurundu, Naga Kurundu, Penirasa Kurundu.
Fenugreek	Guj. Methi-1, Rmt-1 (Rajasthan Methi), Prabha (NLM), Methi No.47, Methi No.-14, Metha, Hebar, Rajendra Kranti (RM-16), Co-1, UM-34, UM-35, Kasuri, Kasuri, Hisar M adhavi, Hisar M ukta, Hisar Suvarna, Hisar Sonali, Pant Ragini, Co.1, Co 2, NRCSS AM 2, NRCSS AM 1, Lam sel.1, RMt-143, RMt.1, RMt 303, RMt-305, Rajendra Abha (Kasuri methi)	Canada: AC Amber, CDC Quatro, CDC Canagreen, CDC Canafen, AC Tristar France: Gers Hungary: Ovari-4, Ovari gold Libia: Ghahkamon Spain: Blidet, Ciadoncha, Obanos Syria: 19 X, D-19, H-26
Turmeric	Nizamabad Bulb, Amruthapani,Armoor, Roma Duggirala,Tekurpeta, Erode,Salem, Chinnanadan, Perianadan, Alleppey Finger, Moovattupuzha, Wynad, Rajapore, Sangli, Karhadi, Waigon, BSR.2, BSR.1, Kanthi, Varna, Sona, Sobha, CO.1, Suroma, Rasmi,, Ranga, Megha turmeric-1, Suguna, Suvarna, IISR Prathiba, IISR Alleppy Supreme, IISR Kedaram, Sudharsana, IISR Prabha, Krishna, Sugandham, Rajendra Sonia, Suranjana	—

Source: Spice board India, http://hortportal.org bala@ciae.res.in. Parthasarathy et al. (2008).

Other Value-added Products

Microencapsulated Flavors

It is prepared by entrapping (spray drying, coacervation, polymerization etc.) the flavoring of a solid matrix and can be release as and when required. *Heat-resistant Pepper:* These are double encapsulated products in which the capsules are rendered as water insoluble coating and the contained flavor will be released only at high temperatures such as in baking process. *Fat-based Pepper:* Fat-based pepper is a blend of pepper oil and/or oleoresin in a liquid edible oil or hydrogenated fat base formulated for use in such products such as

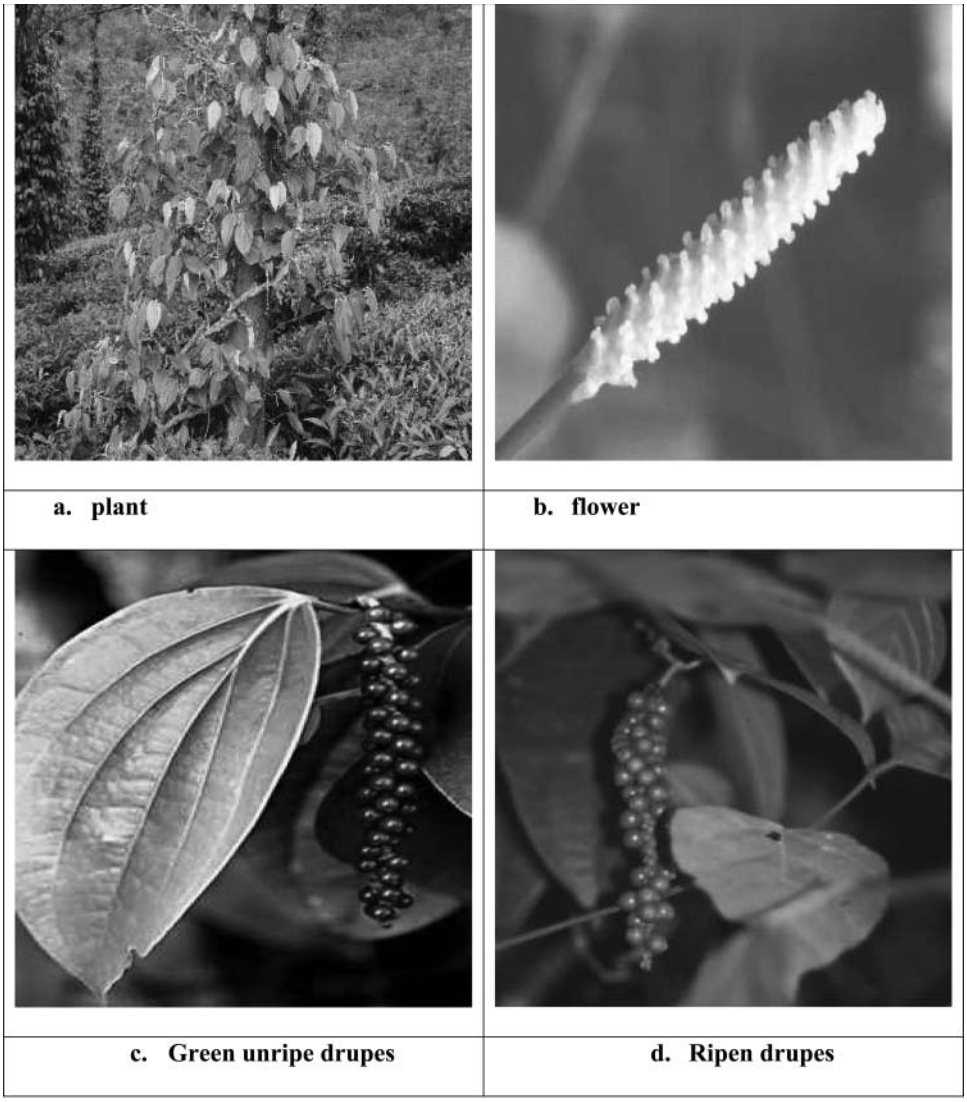


Figure 1 Illustration of pepper in field condition.

mayonnaise etc. *Extruded Spices:* Spices can be sterilized, ground, and encapsulated in a single step by this technique. The product emerges as a spice 'rope' which is cut to pellet size (Scott, 1992).

Uses

Cuisine

It is used as spices for flavor in all types of cuisines viz., stocks, pickles, and sausages. It is also used for masking/deodorizing, pungency, and coloring in cooking process.

Medicine

(i) Antioxidant Action: (Tocopherol and vitamin-C are natural antioxidant)**:** Black pepper in tea can relive from arthritis, nausea, fever, migraine headaches, poor digestion, strep throat, and even coma. Black pepper is also used as insecticide. It can reduce high-fat diet-induced oxidative stress and can treat intermittent fever, neuritis, cold, pains, diseases of throat (Dorman et al., 2000), and malaria (Tipsrisukond et al., 1998). Antioxidant property is due to tocopherol (Saito and Asari, 1976) and polyphenolic content (Revankar and Sen, 1974). Autoxidation of unsaturated fatty acids and proteins is delayed by pepper (Abdel-Fattah and El-Zeany, 1979). *(ii) Analgesic and Antipyretic Actions:* Pepper is used for the treatment of intermittent fever, neuritis, cold, pains and throat diseases, and malaria (Nadkarni, 1976; Lee et al., 1984; Das et al., 1992). *(iii) Central Nervous System Depressant Activity:* Pepper is used for the treatment of epileptic fits and to bring about sleep (Kirtikar and Basu, 1975). *(iv) Mutagenic and Carcinogenic Effects:* Pepper prevents chemical carcinogenesis by stimulating the xenobiotic

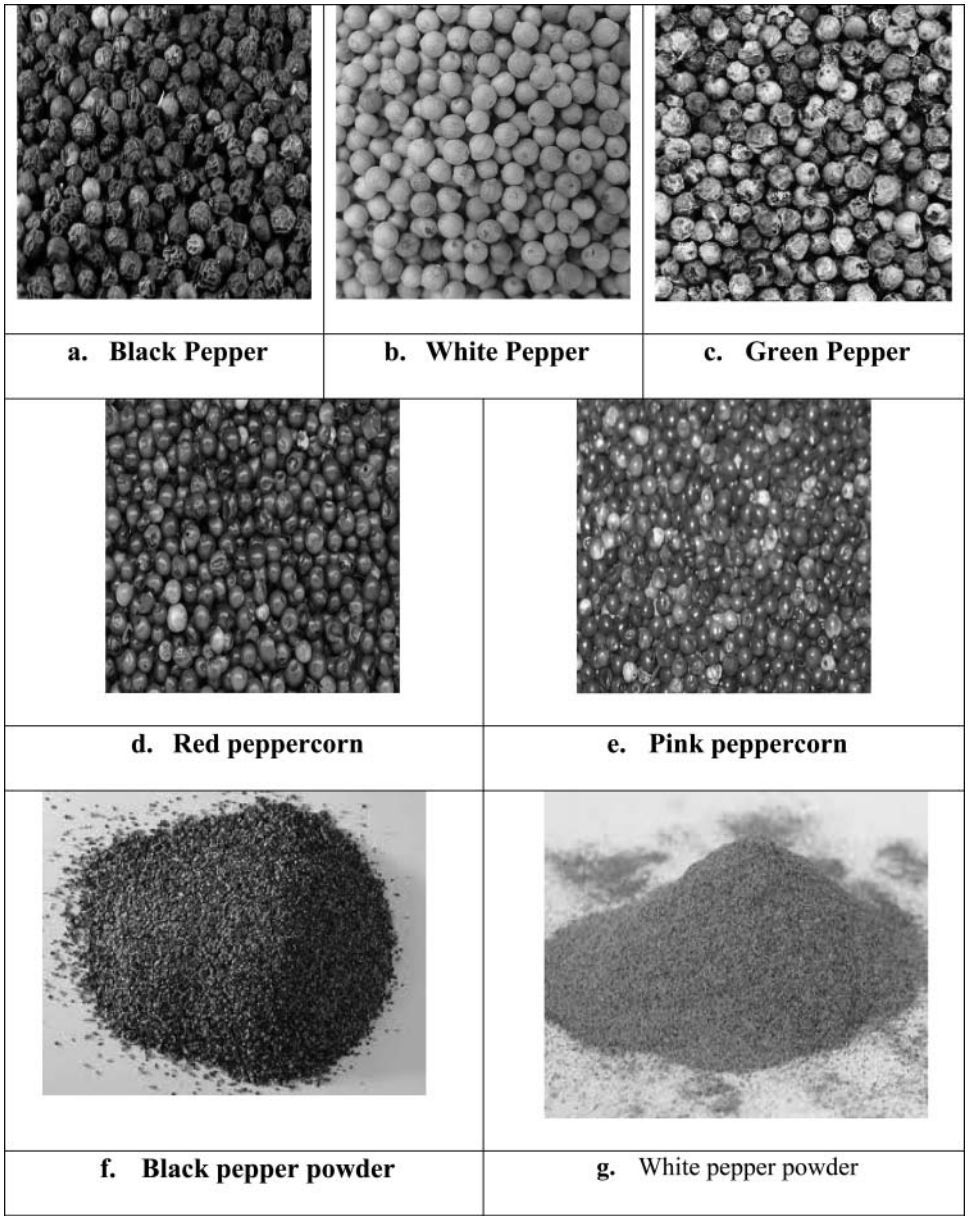


Figure 2 Different types of pepper.

biotransformation enzymes and biotransformation of enzymes have chemoprotective role in liver (Singh and Rao, 1993). (v) *Bio-enhancing Action:* Piperine may induce alterations in membrane dynamics and permeation characteristics along with induction in the synthesis of proteins associated with cytoskeletal function, resulting in an increase in the small intestine absorptive surface, thus assisting efficient permeation through epithelial barrier (Khajuria et al., 2002). *(vi) Insecticidal Action:* The major alkaloid piperine is an insecticide to house flies (Harvill et al., 1943) and volatile oil cause mortality to *Lasioderma serricorne* (cigarette beetle) (Samuel et al., 1984). Alcoholic extract of pepper is effective against cotton ball weevil, rice weevil, and *Drosophila* (Su, 1977; Scott and McKibben, 1978; Barakat et al., 1985). It is used for loss of

Table 6 Primary active compound

Spice	Black pepper	Coriander	Cinnamon	Fenugreek	Turmeric
Active component	Piperine	Linalool	Cinnamaldehyde, Eugenol	Choline, Trigonelline	Curcumin

Table 7 Climatic condition requirements

Parameter	Spice				
	Black pepper	Coriander	Cinnamon	Fenugreek	Turmeric
Plant	Tropical (can't tolerate frost)	Tropical			Tropical and sub-tropical
Temperature (°C)	20–40 (moderate winter climate)	20 – 25	27 –30	8 –27	20 – 40
Rainfall (mm)	2000		1900–2100		>1500
Soil	Red dolerite soils of (KwaZulu) and andesite soil (Soutpansberg) having good water holding capacity	Loamy to moderately heavy soil (black cotton soil) with high moisture retention quality	warm, dry, light soil	fertile, well drained, alkaline, loam soil	sandy and clayey, black, red or alluvial loams, uniform in texture, Rich loamy soils having natural drainage and irrigation facilities
pH	5.5–6.0	4.5–8.0	5.5–6.5	5.3–8.2	
Humus	High				High

appetite, curing intestinal worms, bloating and flatulence, toothache, aches, eczema, tongue injuries, constipation, hemorrhoids, excessive thirst, pimples, improving circulation, reducing arthritic pain and boosting immunity (Pruthi, 1993). It also stimulates taste buds to increase hydrochloric acid secretion, organs to produce increased flow of saliva and gastric.

Piperine acts as a thermogenic compound by enhancing the thermogenesis of lipid and accelerates energy metabolism, also increases the secretion and produces β-endorphin in the brain. It reduces inflammation, has liver protective action, inhibit the enzyme, increase the bioavailability of various compounds like curcumin. Piperidine is used in pharmaceutical drugs such as raloxifene and minoxidil. Piperidine can be used as a solvent in solid phase peptide synthesis and production of dipiperidinyl dithium tetrasulfide, which is used as a rubber vulcanization accelerator. Calcium and potassium present in pepper are good for health, potassium regulates blood pressure and selenium maintains bones formation, nails hair, follicles and teeth and for proper functioning of brains. Vitamin A & K of black pepper oil (β-carotene) are very good antioxidant and maintains circulatory and metabolic functions, muscles, bones etc. Essential oil has good rubefacient and analegistic properties for skin care. Pungency of pepper suppresses all kind of infection, strengthens the nervous system, good digestive agent, improves gastrointestinal condition, and normalizes the peristaltic system.

Table 8 Harvesting time for pepper for different products properties

Maturity at harvest	Products
Fully ripe	White pepper
Fully mature and near ripe.	Black pepper
4–5 months	Canned pepper
10–15 days before full maturity	Dehydrated green
15–20 days before maturity	Oleoresin/pepper oil
Fully mature with maximum starch	Pepper powder

Source: Govindarajan (1979).

Coriander

Coriander (*Coriandrum sativum* L.) is an annual and herbaceous plant (Fig. 4a,b,c), belonging to a family of *Umbelliferae* (Gupta et al., 1991, Raghavan, 2000). The fresh leaves of plant are known as cilantro. It is a soft, hairless plant grows up to 60 cm tall. The fruit is a globular (3–5 mm dia) each contains two seeds.

CHEMICAL COMPOSITION

The primary components including mineral and vitamin contents viz., calcium, phosphorus, iron, carotene, sodium, potassium, oxalic acid, thiamine, riboflavin, niacin, and vitamin C of coriander is depicted in Table 10. The taste of fresh herb is due to an essential oil that is made up of aliphatic aldehydes. Seed is composed of essential oils mainly of linalool (50–60%, responsible for aroma, Table 6) and terpenes (20%) like pinenes, γ-tepinene, myrcene, camphene, phell andrenes, α-ter pinene, limonene, cymene, and monoterpenoid. The odor and flavor of mature seed and fresh herbage are completely different. The main chemical components in the oil are borneol, linalool, cineole, cymene, terpineol, dipentene, phellandrene, pinene, and terpinolene. Linalool (monoterpenoid) is the primary constituent of coriander oil (Tashinen and Nykanen, 1975; Coleman and Lawrence, 1992; Wichtl, 1994; Leung and Foster, 1996; Pino et al., 1996). The leaf oil contain forty-four compounds mostly of aromatic acids containing 2-decenoic acid (30.8%), E-11-tetradecenoic acid (13.4%), capric acid (12.7%), undecyl alcohol (6.4%), tridecanoic acid (5.5%), and undecanoic acid (7.1%). Aliphatic aldehydes (mainly C10-C16 aldehydes) are predominant in the fresh herb oil. The seed oil contains fifty-three compounds mostly of linalool (37.7%), geranyl acetate (17.6%), and γ-terpinene (14.4%). The essential oil and fatty oil content varies between 0.03–2.6% and 9.9–27.7%. Respectively other constituents are crude protein (11.5–21.3%), fat (17.8–19.15%), crude fiber (28.4–29.1%), and ash contents (4.9–6.0%).

Figure 3 Pepper thresher.

Postharvesting/Processing

Harvesting

(i) leaves (Fig. 4b): These are harvested at 60–75 days after sowing, bunched and stored at 90% humidity, temperature below 5°C for 24–36 h. These leaves can be dried or dehydrated to coarse powder or rubbed leaf powder. *(ii) Seeds* (Fig. 4f): Early in the morning or late evening at 66% maturity (Fig. 4d,e), the harvesting is done by cutting the whole plant when 60% of seeds in the main umbel attain the desired size and color to minimize the breakage. Threshing is done by beating the plants to remove seeds. *Drying:* The plants are withered for 2 days and dried to approximately 18% moisture content. Then threshed and again dried in shade to attain 9% moisture content. Artificial drying can be done in the temperature range of 80–90°C. *Essential oil extraction:* The seed is ground immediately prior to distillation to increase oil yield and reduce the distillation time. The essential oil content in the range of 0.1–1.5% and contains a range of different essential oils.

Table 9 Classification of cultivars based on the berry size

Large size (>4.25mm)	Medium size (3.25–4.25 mm)	Small size (<3.25mm)
Panniyur-1	Karimunda	Kurialmundi
Valiakaniakkadan	Arakulammunda	Narayakodi
Vadakkan	Ottaplackal	
Karuvilanchi	Kuthiravally	
	Kaniakkadan	
	Neelamundi	
	Balankotta	

Source: Gopalam et al. (1991).

Value-added Product of Coriander

Coriander Powder

Coriander powder (Fig. 4g) is produced by grinding (hammer mill etc.) the seeds. *Coriander oil:* Coriander oil is a colorless, pale yellow liquid, having characteristic odor and taste. The seeds also contain fats oil (19–20%) which is mixture of glycerides of palmitic, oleic, linoleic, and petroselinic acids. Coriander oil is used as an ingredient in the preparation of liquors and medicine. *Coriander seed:* Seeds are used in culninary purpose.

Uses

Leaves

(i) Cuisines: It is used in chutneys, sauces, curries, and soups for flavor and aroma. *(ii) Medicine:* Herb has antispasmodic, antibacterial, antioxidative, and lipid-lowering actions (due to volatile oils). It is useful in small pox. *Seeds and oil: (i) Cuisines:* Coriander seeds are major constituent of curry powder. It is used for flavoring candies, breads, cakes, pastries, biscuits, buns pudding, pickle spices, seasonings, stews and soups, vegetable dishes, meat, fish and salads, soda and syrups, beverage (also alcoholic), cookies, and sausages (Diederichsen, 1996). It is also used in tobacco industry. *(ii) Medicine:* It is used as analgesic, digestive, deodorant, natural antibiotic (protection against food-borne illnesses caused by *Salmonella*), anti-rheumatic, anti-cancer (due to phthalides and polyacetylenes, phytochemcials compounds), antioxidant, antidiabetic (Insulin-releasing and insulin-like activity), anti-

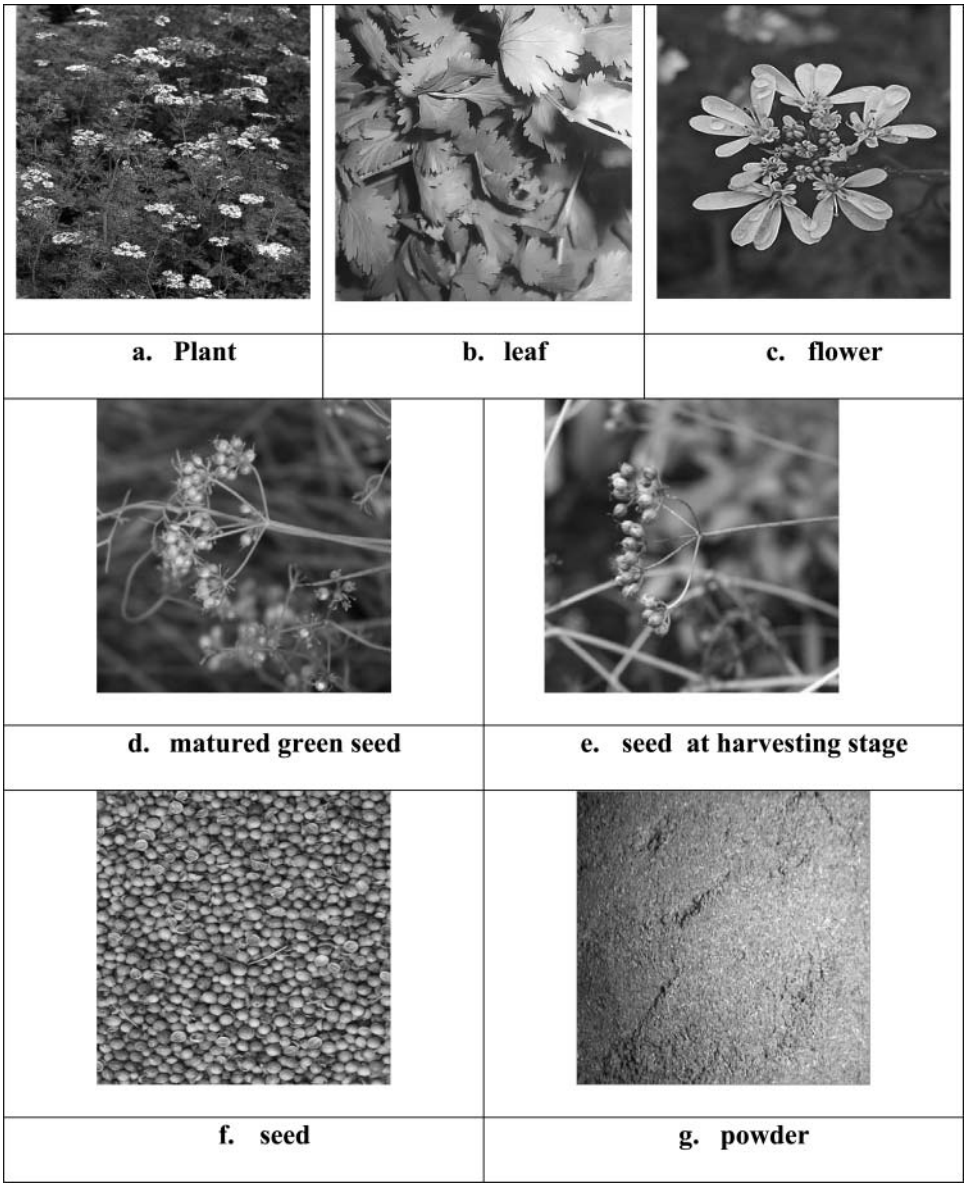


Figure 4 Illustration of coriander in field condition.

inflammatory galactagogue, antispasmodic, diaphoretic, fungicidal, lipolytic. It also acts as alterative, antibilious, aphrodisiac, appetizer, aromatic, depurative, diuretic, refrigerant, stimulant, tonic (Norman, 1990) and stomachic, carminative and antispasmodic agent (Alison and Peter, 1999). Coriander seed is a rich source of minerals like iron, magnesium, and high content of dietary fiber. It is used as a drug for indigestion, against worms, rheumatism, and pain in the joints (Wichtl, 1994; Wangensteen et al., 2004). It can control blood sugar, cholesterol, and free radical production, relieve intestinal gas, refresh and uplift the mind, useful in migraine, tension, relieve wind, and cramps, while revitalizing the glandular system. It can treat fever, cold, flu, stomach disorders, digestive problem, diarrhea, dyspeptic complaints, mild gastrointestinal upsets, flatulence, colic, loss of appetite, anxiety, convulsions, dyspepsia, and insomnia (Breevort, 1996; De Smet, 2002). It has hypolipidemic effect, reduces cholesterol and used in laxative (stimulate to empty bowels) remedies. It settles spasms in the gut and counters the effects of nervous tension. The raw seed is chewed to stimulate the flow of gastric juices and to cure foul breath, and it sweeten the breath after garlic has been eaten and act as a mouthwash. Combination with caraway and cardamom seeds is useful in vomiting. Coriander oil acts as a general cleanser of the body, to get rid of toxins and fluid wastes. In vapor therapy, coriander oil can stimulate the mind and ease fatigue, while assisting with eating disorders and improving appetite. It is used as massage oil and as part of a cream or lotion,

Table 10 Nutritional facts of spices per 100 g

Parameters	Black pepper*	Coriander+	Cinnamon	Fenugreek	Turmeric
Moisture content (%)	8	6.3	5.1	6.3	13.1
Food energy (kcal)	400	1.3	258	0.37	354
Protein (g)	10	19.6	2	10	6.3
Fat (g)	10.2	19.6	2	10	5.1
Carbohydrates (g)	66.5	24	0.5	42.3	69.4
Ash (g)	4.6	0.8	2.4	13.4	6.02
Calcium (g)	0.4	0.8		1.3	0.183
Phosphorus (mg)	160	440	0.083	480	
Sodium (mg)	10	820	42.4	90	38
Potassium (mg)	1200	1200		1700	268
Iron (mg)	17	0.006	134.7	11	41.42
Zinc (mg)			7		
Thiamine (mg)	0.07	0.23	2.6		0.152
Riboflavin (mg)	0.21	0.26			0.233
Niacin (mg)	0.80	3.2		6	5.14
Ascorbic acid (mg)	ND		1.332		
Vitamin A (μg)		0.23		312	
Vitamin B_1 (mg)		0.26	337	0.41	
Vitamin B_2 (mg)		0.23		0.36	
Vitamin C (mg)		12		12	25.9
Vitamin E (mg)		31.5	27	12	
Vitamin k (μg)			0.0104		
Dietary fiber (g)		31.5	31.2	18.5	21.1
Chromium (mg)			33		
Cholesterol			0.4		
Volatile oil (g)		0.3			
Nonvolatile (g)		22			

*Tainter and Grenis (2001); +Pruthi (1979), ND = Non detectable.

coriander oil can help with tension, mental fatigue, migraine, muscle spasms, arthritis, improves appetite and alleviates gastric insufficiency and distress (stomachic), relieves intestinal cramping and has anti-inflammatory action. Volatile components of oil have antibacterial and antioxidative property and inhibit micro-organisms growth and lipid peroxidation.

Other Uses

Coriander is used in aromatherapy, perfumes, lotions, soap, and shampoos (Anonymous, 1950; Chopra et al., 1956; Ghani, 2003). *Adverse effect:* Sometimes if it is used too freely, the seeds can have a narcotic effect.

Cinnamon

Cinnamon *(Cinnamomum zeylanicum)* is an evergreen shrub or small tree (Fig. 5a) of laurel family *Lauraceae*. It is an important spice for flavoring of foods. Cultivars of cinnamon are given in the Table 5.

CHEMICAL COMPOSITION

The major component are depicted in the Table 10. Cinnamon oil includes many components viz., cinnamaldehyde (65–80%), trans-cinnamic acid (5–10%) and eugenol (4–10%,) (Table 6); other constituents include cinnamic alcohol, terpenes such as limonene, tannins, mucilages, oligomerprocyanidin, traces of coumarin, α-Thafone, α-pinene, benzaldehyde, heptanol, sabinene, 1-octen-3-ol, β-pinene, myrcene, *p*-cymene, limonene, β-phellandrene, 1,8-cineole, γ-terpinene, octanol, terpinen-4, α-terpineol, trans-carveol, nerol, geraniol, geranial, neryl acetate, cinnamyl alcohol, dihyroeugenol, ethylcis-cinnamate, *t*-Methyl cinnamate, isoeugenol, cis-Caryophyllene, *t*-Cinnamic acid, cinnamyl acetate, α-Caryophyllene, E-ethyl cinnamate. Active components are cinnamaldehyde, cinnamyl acetate, cinnamyl alcohol, eugenol (found mostly in the leaves), cinnamic acid, weiterhin, mucilage, diterpenes, proanthocyanidins, β-caryophyllene, linalool, and methyl chavicol.

Postharvesting/Processing

Harvesting

It is harvested early in the morning during wet season (September to November) since rainfall facilitates the peeling of bark. Harvesting involves the removal of stems. *Preparation of barks:* For the preparation of cinnamon bark, tender stems (1.2–5 cm) are removed and used for mulching. Removed leaves (Fig. 5b) can be used for oil distillation. Barks are

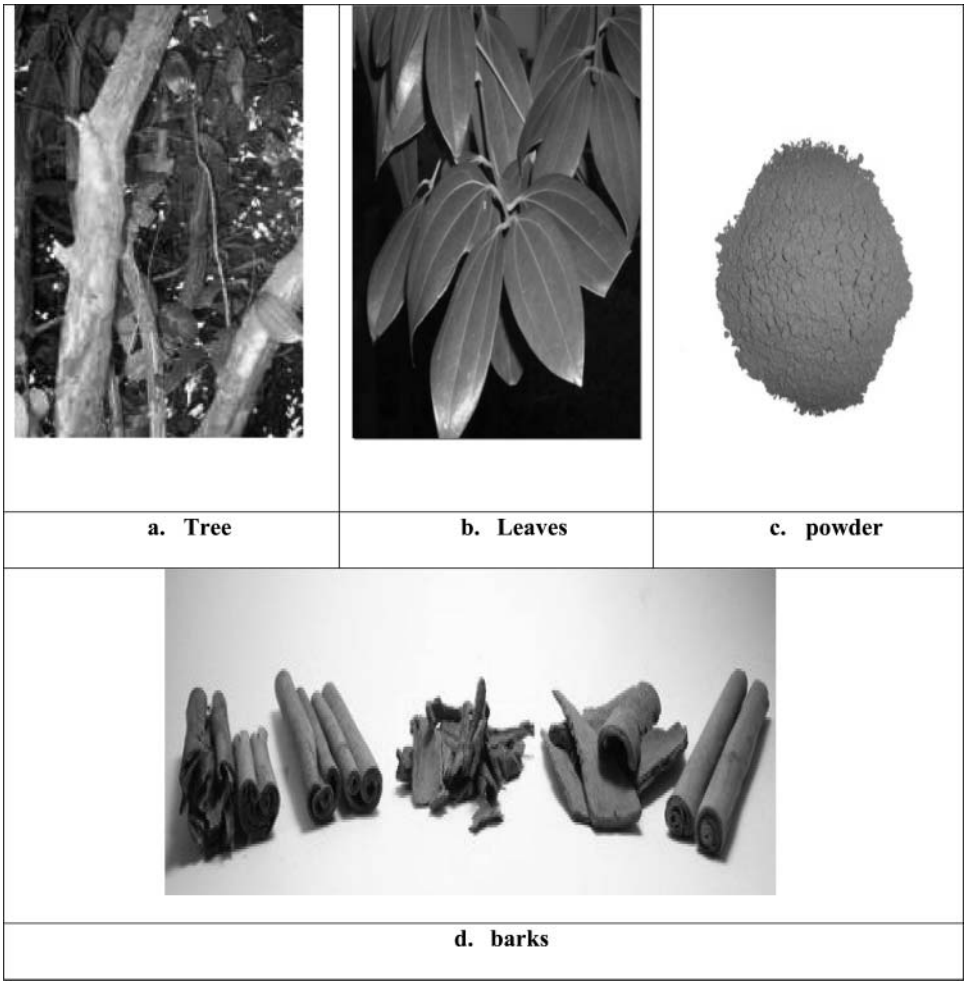


Figure 5 Illustration of cinnamon under different condition.

produced by making longitudinal cuts (at 30 cm intervals) on either side of the stem and eased off using pointed knife (stainless steel or brass). Stripped stem is rubbed with a brass rod to loosen the inner bark. The curled pieces of peeled bark (quills) are placed one inside another to make 1m long 'compound quills.' The best quills are placed on the outside and broken and small pieces in the center. *Drying:* The 'compound quills' are placed on coir rope racks and dried in the shade to prevent warping. *Storage*: Cinnamon bark (Fig. 5d) can be stored in a dark, cool, dry place for 2 to 3 years. *Grading***:** The quality of the cinnamon depends on the bark thickness, appearance and aroma and flavor.

Value Added Products

Cinnamon Powder

Cinnamon powder (Fig. 5c) is obtained by grinding of the barks. *Cinnamon oil:* Cinnamon oil is obtained by steam or water distillation.

Uses

Cuisines

Cinnamon bark is used as spice condiment and flavoring material. It finds application in chocolate, spicy candies, apple pie, donuts, cinnamon buns, tea, hot cocoa, liqueurs, cereals, bread-based dishes, and fruits (especially apples), pickles preparation. It is also used to flavor rice, chicken or ham, cakes and sweet, etc. (Shumaila Gul and Mahpara Safdar, 2009). *Medicine:* Medicinal parts of cinnamon plant are outer bark, inner bark, leaves. It is used to treat stomach, diarrhea (Skidmore- Roth, 2003), bronchitis, coughs, respiratory ailments (Martinez, 1989), loss of appetite, dyspepsia (Blumenthal, 1998), gastritis, blood circulation disturbance, and inflammatory (Wang et al., 2009). It is used for invigorating tonic, cold, nausea, vomiting, flatulence, asthma, paralysis, toothache, bad breath, treating diarrhea, indigestion, gas and bloating, stomach upset, gastric ulcers, nervous disorders, fatigue, hearing loss, excessive menstruation, uterus disorders, gonorrhea, uterine hemorrhage, menorrhagia, hypertension (high blood

pressure), curing minor bacterial and fungal infections of skin, menopausal symptoms, rheumatic conditions, bacteria, destroying fungi, including the molds that produce carcinogenic aflatoxins, preventing the damage to cell membranes by free radicals. It has antipyretic, antiallergenic, analgesic, antitussive (Gurdip et al., 2008) and chemopreventive activities (Sabulal et al., 2007). *(i) Anti-oxidant Actions:* It is beneficial against free radicals (Lee and Shibamoto, 2002; Dragland et al., 2003; Jayaprakasha et al., 2002; 2003). *(ii) Anti-Clotting Actions:* Cinnamaldehyde (cinnamic aldehyde) has a effects on blood platelets by helps preventing unwanted clumping. *(iii) Anti-Microbial Actions:* Cinnamon essential oil inhibits the growth of bacteria (*Bacillus cereus, Legionella pneumophila*), fungi, yeast (*Candida*) and food borne pathogens. *Blood Sugar Control:* Polyphenol in the cinnamon stimulates the insulin receptors, and also inhibiting an enzyme that inactivates them, thereby increasing cells' ability to use glucose. Cinnamon oil has the significant effect in type II diabetes (Khan et al., 2003). *(iv) Cinnamon's Scent Boosts Brain Function:* Cinnamon odor boosts brain activity, chewing cinnamon flavored gum or cinnamon smell enhances study participants' cognitive processing, virtual recognition memory, and working memory. Calcium and fiber improve colon health and protect against heart disease: Cinnamon essential oil is a good source of manganese, iron, and calcium. Calcium and fiber remove bile salt from the body thereby reducing the risk of colon cancer, prevents atherosclerosis and heart disease, and provide relief from constipation or diarrhea.

Other Uses

Cinnamon is also used as an insect repellent and used in nasal sprays and suntan lotions, gum, mouthwash, toothpaste, face cream, hair oils, flavored cinnamon toothpicks, perfumes, potpourri, scented sprays, scented candles and soaps**.** *Adverse Reactions:* It can cause irritation to oral mucous membranes (Allen and Blozis, 1988; Miller et al., 1992; Sedghizadeh and Allen, 2002), cause skin rashes, stomach bleeding and have stimulating effects on uterus in pregnant women when taken in high doses.

Fenugreek

Fenugreek (*Trigonella foenum graecum*) is an annual herb (Fig. 6a) (30–60 cm tall) belonging to family *Leguminosae*. It is native to southern Europe and Asia. Its flower is axillary white to yellowish, and 3–15 cm long thin pointed (Fig. 6c) beaked pods, which contain 10–20 oblong greenish-brown seeds with unique hooplike groove.

Chemical Composition

Fenugreek Seed

The major constituents are given in the Table 10. The active components in fenugreek seed (Fig. 6d) are trigonelline, galactomannan, choline (Table 6), vitamin C, steroid saponins, flavonoids, trigonelline, 4-hydroxyisoleucine, and sotolon. Chemical Composition: Greens and seed are rich in choline and contain sapogenins, trigonelline, magnesium, copper, sulphur, chlorine, manganese, zinc, chromium, β-carotene, thiamine, riboflavin, nicotinic acid and folic acid. The endosperm of seed is rich in polysaccharide galactomannan. The young seeds mainly contain carbohydrates and sugar and mature seeds contain amino acid, fatty acid, vitamins, and saponins, large quantity of folic acid (84 mg/100 g), yamogenin, disogenin, gitogenin, neogitogenin, homorientin saponaretin, neogigogenin, and trigogenin. 4, 5. *Fenugreek Oil:* Fenugreek oil (6–8%) has a fetid odor (may resemble that of roasted coffee or maple syrup) and bitter taste with marked drying properties. Its specific gravity is 0.91. It has acid value (1–2), saponification value (178–183), iodine value (115), unsaponifiable matter (3.9%) (contains the lactation-stimulating factor) and fatty acid composition of palmitic (9.6%), stearic (4.9%), arachidic (2%), oleic (35.1%), linoleic, (33.7%), and α-linolenic (13.8%). *Fenugreek Fiber:* About 50% dry weight of seeds is edible dietary fiber and 30% is gel-forming soluble fiber. The insoluble fiber, (20%) is bulk-forming property like wheat bran. Dietary fiber from fenugreek is very stable, more shelf life and withstands frying, baking, cooking, and freezing. Dietary fiber with a high water retention capacity is made into jelly, spreads, and thickener. Flour fortified with 8–10% fenugreek dietary fiber has been used to prepare bakery foods like pizza, bread, muffins, and cakes. Fenugreek dietary fiber has also been incorporated into flour to make chips, flat-bread (chapathi), wafers (papads), and taco shells.

Postharvesting/Processing

Greens are harvested at 3 or 4 leaved stage *i.e.*, (120–150 days) after sowing after which saponin content increases, making them bitterer. The seeds are harvested 30–35 days after flowering or 155–165 days after sowing.

Uses

Cuisine

Fenugreek leaves (Fig. 6b) are used as green leafy vegetables in diet and forage crop. Fenugreeks are used in many baked goods and imitation maple syrup for maple aroma and flavor. The seeds are hot with a sharp bitter taste. It contains dietary fiber having nutraceutical value. Fenugreek is used to enhance flavor, color, and to modify texture foods. Ground seeds are used in curries. It is also used in tobacco industry. *Medicine:* It is used in numerous medicinal/pharmaceutical. Some of them are: *(i) Immunomodulatory:* It has protective effect against CP-induced (Cyclophosphamide drug) urotoxicity. It also has anti-inflammatory, antipyretic, hypoglycemic,

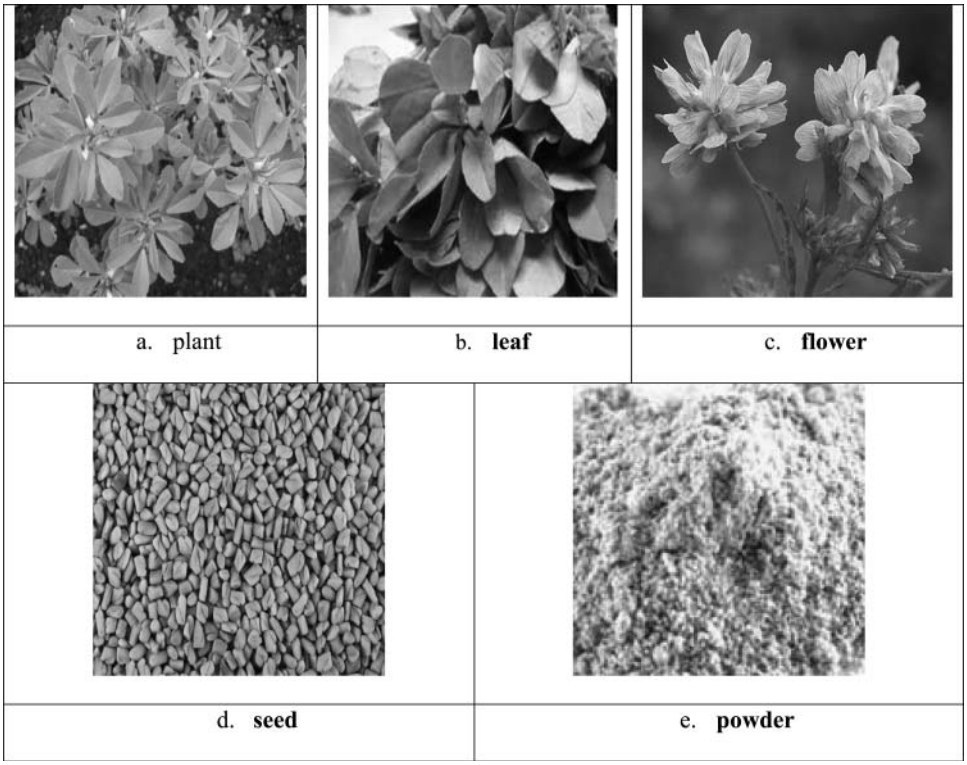


Figure 6 Illustration of fenugreek under different stages.

immunomodulatory, hypoglycemic, and anti-diabetic properties. *(ii) Antioxidant:* Flavonoids of fenugreek extract possess anti-oxidant and free radical scavenging activities (Bajpai et al., 2005). Quercetin has protective effect against CP-induced hemorrhagic cystitis, fenugreek extract prevent both lipid peroxidation (LPO) (Kaviarasan et al., 2004; Dixit et al., 2005) and hemolysis in red blood cells (RBC) (Dixit et al., 2005), protects cellular structures from oxidative damage, aqueous methanolic and polyphenolic components extract has antiradical and antioxidant activity. *(iii) Antidiabetic:* Fenugreek seed powder has effect on enzyme changes, lowering the blood glucose and prevents the lowering of cortical thickness of the thymic lobules level in diabetic (type II diabetics or noninsulin-dependent diabetes mellitus). Trigonelline, (alkaloid) present in the fenugreek reduce glycosuria in diabetes**.** *(iv) Anticancer:* Flavonoids (anti-tumorigenic) induce apoptosis (death of cells) in human carcinoma cells, lung tumor cell lines, colon cancer cells, breast cancer cells, prostate cancer cells, stomach cancer cells, brain tumor cells, head and neck squamous carcinoma3 and cervical cancer cells and have stimulatory effects on macrophages. Diosgenin is useful in cancer therapy (Aggarwal and Shishodia, 2004). *(v) Chemopreventive:* Fenugreek seeds extract inhibit 7, 12-Dimethylbenzanthracene induced mammary hyperplasia and antibreast cancer protective effect. *(vi) Complementary Cancer Therapy:* Fenugreek extract prevents the cyclophosphamide-induced apoptosis caused by cyclophosphamide (CP, an anticancer drug) (Bhatia et al., 2006). (vii) *Gastroprotective:* The aqueous extract and gel fraction isolates from seeds have significant ulcer protective effects, cytoprotective effect, anti-secretory action, effects on mucosal glycoproteins and prevent lesion formation. Seeds prevent rise in lipid peroxidation induced there by lowering mucosal injury. Some constituent of seed stimulate the pancreas to release digestive enzymes, thereby aiding in digestion. *(viii) Hypocholesterolemic:* The ethanol extract from fenugreek seeds contain hypocholesterolemic components, which can reduce serum cholesterol (Stark and Madar, 1993; Sharma et al., 1996; Basch et al., 2003) and other supplements can also lower tri glyceride and low-density lipoprotein (Basch et al., 2003). Other than these effects fenugreek has anti-inflammatory, anti-obesity, antipyretic, antiseptic, hypocholesterolemic, aphrodisiac, astringent, urotoxic, suppurative, aperient, diuretic, emmenagogue, demulcent emollient, expectorant, and anthelmintic action, digestive stimulant, anthelmentic and hepatoprotective actions. Phyto extract of fenugreek is a good source of phytochemicals. It is ease and useful in hemorrhoids and constipation, fever, chronic coughs, sore throat, boils, mouth ulcers, leg ulcers, chapped lips, eyes/swollen, baldness, piles, vomiting, dropsy, gallbladder problems, abscesses, anemia, asthma, cure leprosy, wound healing, body odor, hair falling, external and internal swellings and burns, eczema, local inflammation, sinus problems astringent to the bowels, myalgia, lymphadenitis, gout, bronchitis, cellulitis, heart burn, production of hormones acid reflux, loss of appetite, dyspepsia, gastritis, atherosclerosis, beriberi, hernia, tuberculosis, enlargement of the liver and the spleen, high serum cholesterol and triglycerides, heart disease, promoting lactation, kidney ailments, lung infections. Saponins and

Alkaloids present in the fenugreek contribute gastric stimulation, increase acidity, increased appetite and increase lean muscle mass in women. Diosgenin, the main sapogenin (an estrogen precursor) may help in managing menopause, induces release of testosterone in males, increases secretory functions and induces uterine contractions in females. Saponins can reduce cholesterol, to a small extent through hormone synthesis without effect on triglycerides and bind to dietary lipids. The seed is a source of steroidal saponin diosgenin, which can be used to manufacture many pharmaceuticals, such as progesterone. Fenugreek can ease childbirth and increase milk flow and useful in menstrual pain.

Other Uses

Fenugreek could reduce soil erosion by about 90%. The roots of legumes help break up compacted soil layers and are effective soil builders. Fenugreek also reduces manure odor. The oil is also used for soap, cosmetic purposes, with traces used in perfumes, and used as insect and pest repellent. Fenugreek seeds are mixed with yogurt which is used as hair conditioner and seeds are used in tea. *Adverse effect:* Sometimes fenugreek seed powder (Fig. 6e) can cause food allergies, nasal congestion, hoarseness, persistent coughing, and inhalation of powder cause rhinorrhea, wheezing and fainting, numbness of head, facial angioedema, and wheezing after applying fenugreek paste to the scalp as a dandruff treatment. High dose can cause mild central nervous stimulation, rapid respiration, tremors, diarrhea, dyspepsia, abdominal distention, and flatulence. Consumption of fenugreek by pregnant women just before delivery may cause the neonate to have an unusual body odor, which may be confused with maple syrup disease. Loss of consciousness may also occur in children drinking tea made from fenugreek (Fig. 7a).

Turmeric

Turmeric (*Curcuma longa*) is a medicinal plant of family *Zingiberaceae*. It is a perennial plant having a short stem (Fig. 7a) with large oblong leaves and bears ovate, pyriform or oblong rhizomes, which are often branched and brownish-yellow in color. Rhizomes may be bulbs, fingers, and splits. Fingers are the secondary branches of mother rhizome (bulb). There are thirty varieties of turmeric available. Some of the important varieties in India are alleppey (6.5% curcumin), madras (3.5% curcumin), West Indian, duggirala, tekurpeta, sugandham, amalapuram, moovattupuzhan, Lakadong etc.

CHEMICAL COMPOSITION

Turmeric contains mainly essential oils (5%) and curcumin (5%), (polyphenol), protein (6.3%), fat, minerals, carbohydrates, and moisture (Table 6). The essential oil has *a*-phellandrene (1%), sabinene (0.6%), cineol (1%), borneol (0.5%), zingiberene (25%), and sesquiterpines (53%). Curcumin (diferuloylmethane) (3–4%) or curcuminoid is responsible for yellow color, and comprises curcumin I (94%), curcumin II (6%), and curcumin III (0.3%). The ketonic sesquiterpenes (*ar*-turmerone and turmerone) are responsible for aroma of turmeric (Rupe *et al*. (1934). Curcumin (1, 7-*bis* (4-hydroxy-3-methoxy prenyl)-1, 6-heptadiene-3, 5-dione) $C_{21}H_{20}O_6$ (Vogel and Pelletier, 1818). Curcumin exist in two tautomeric forms (keto and enol). The keto form is preferred in solid phase and the enol form in solution.

Postharvesting/Processing

Turmeric crops are harvested during July to march (7–9 months) depending upon the time of sowing and the leaves turn to dry and the color is light brown and yellow. The land is ploughed and rhizomes are carefully lifted. Harvested rhizomes are cleaned of mud and other extraneous matter. *Sweating:* The leaves are removed from plant and roots are carefully washed to remove soil. Any leaf scales and long roots are trimmed off. The fingers of rhizomes are removed from main central bulb. The bulb and fingers are heaped separately, covered with leaves and left to sweat for one day. *Curing:* Green rhizomes are boiled (45–60 min) in water to soften the roots and remove raw color. Boiling is stopped when froth comes out and white fumes appear giving out a typical odor (Fig. 7b,c,d). *Drying:* They are dried to reach final moisture content of 5–10%. The rounds and fingers are dried separately. Rhizome pieces (Fig. 7b,c,d) are kept away from the sunlight to prevent the color loss. Drying time can be reduced by slicing the rhizomes which improves the final product quality. *Polishing:* Rhizomes are polished to remove the rough surface by rubbing against the hard surface of drying-floor, trampled under feet or by polishing drums. Sometimes rhizomes are sprinkled with turmeric powder (mixed with little water) during the final polishing to obtain good color. *Grading:* Rhizomes are graded into bulb, fingers, and splits. *Storage:* Rhizomes are stored in cool and dry environment, away from direct sunlight. *Quality assessment:* It depends mainly on curcumin (deep, yellow color pigment) content, low 'bitter-principle' content, appearance, shape, and size of rhizome, volatile oil (aroma and flavor). The aroma should be musky, pepper-like character and flavor should be aromatic and somewhat bitter.

Value-added Products

Dried Rhizome

It comes in bulbs fingers and splits. Dried Turmeric (Fig. 8a) is used to process powder or oleoresin. *Turmeric Powder):* Turmeric powder (Fig. 8b) is a major ingredient in curry powder and pastes. It is mostly use to color and flavor mustard.

Oleoresins: It is obtained by solvent extraction of powdered or comminutated rhizome. This process yields about 12% of an orange/red viscous liquid and contains various proportions of coloring matter, i.e. curcuminoids (40–55%), volatile oils (15–20%) which impart flavor to the product and nonvolatile fatty and resinous materials. The curcuminoids, consisting of curcumin can be purified to a crystalline material, and are used preferably in product development. *Essential oil:* It is obtained by distillation or by supercritical fluid extraction of powdered rhizome i.e. a product of curcuminoids purification from oleoresins.

Uses

Cuisines

Turmeric is, used as a food additive to flavor and color foodstuffs like cheeses, salad dressings, margarine, mustard paste (Asta, 2002), yoghurts, cakes, biscuits, popcorn, cereals, sauces, etc. and a principal ingredient in curry powder (Govindarajan, 1980; Tainter and Grenis, 2001). It is used in nonalcoholic beverages, for garnishing and in some ice creams (Perotti, 1975). Curcumin (solution and powder) dissolved in alcohol is used for pickles and mustard. Turmeric Oleoresin is used in brine pickle, mayonnaise and relish formulation (Eiserlie, 1966; Cripps, 1967).

Medicine

Turmeric is used to cure, cuts and burns, promote healing, fever, cold, mucus in the throat, watery discharges like leukorrhea, any pus in the eyes, ears, or in wounds, dental problems (due to the presence of fluoride), urinary disorders, diarrhea, ulcers, insanity, lactation problems, poisoning, conjunctivitis gastrointestinal upsets, colic, arthritis pain, low energy, menstrual and abdominal problems. It dispel worms, strengthen the body, dissolve gallstones, decreases congestion and inflammation from stagnant mucous membranes, purifies blood, helps in expelling gas from the intestines (carminative agent), protects lungs and liver from pollution, toxins (like major hepatoxins and aflatoxin) and pathogens, rebuild the liver after being attacked by hepatoxins, protects the lungs from pollution and toxins, regulate the female reproductive system and purifies the uterus and breast milk, in men it purifies and builds semen, and helps in preventing the blockage of arteries. It is against biliary disorders, cough, anorexia, diabetic wounds, rheumatism, and sinusitis (Araujo and Leon, 2002). Turmeric can benefit from Colitis, Crohn's disease, post-giardia or post salmonella conditions and good effect on digestive system. Turmeric used as a stomachic, tonic and blood purifier, and in the prevention and treatment of skin diseases (Anonymous, 2001). It has tetrahydrocurcuminoids which may have antioxidant property. Turmeric oleoresin shows inhibitory activity against different fungi. Turmerone is a mosquito repellent and drug for the treatment of respiratory disease and dermatophytosis. Ether, crude ethanol extract chloroform extracts and oil have an antifungal effects against *Aspergillus flavus, Aspergillus parasiticus, Fusarium moniliforme*, and *Penicillium digitatum*. Turmeric oil also has antibacterial, antimutagenic, and anti-inflammatory property. The

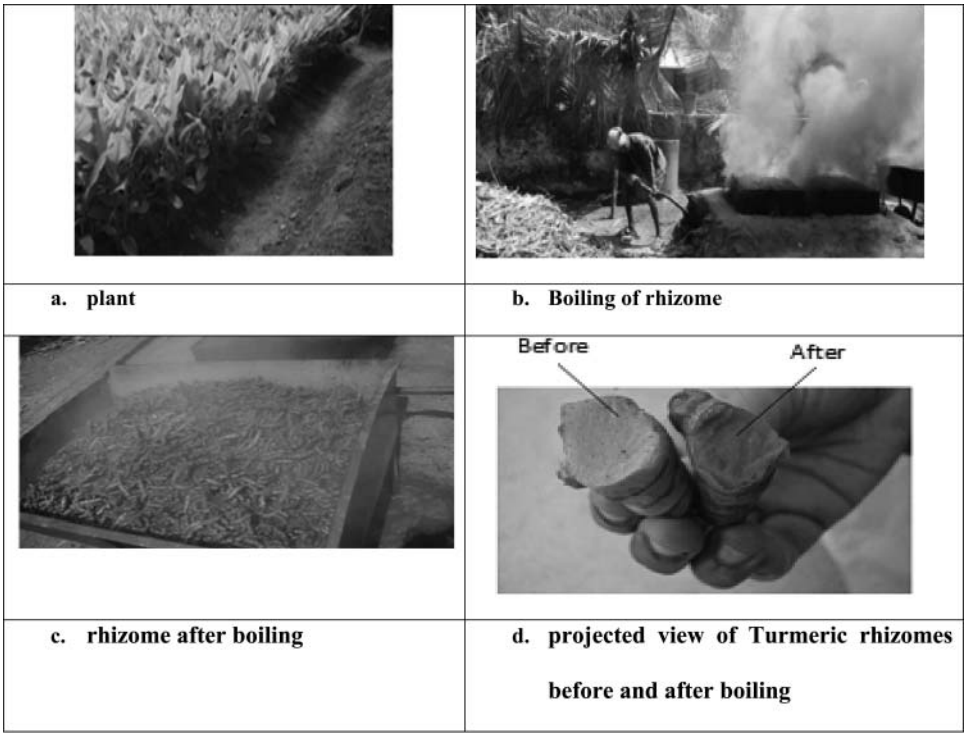


Figure 7 Turmeric processing.

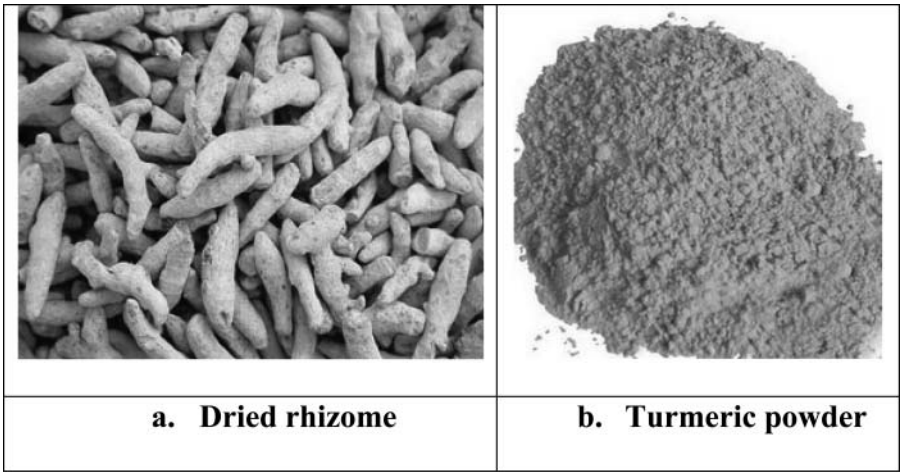


Figure 8 Illustration of turmeric in field condition.

ethanol extract of the rhizomes has anti-*Entamoeba histolytica* activity. *Other uses:* Turmeric finds application in making dyes.

Curcumin is the active compound in the turmeric poses many medicinal properties (Table 6). Anti-inflammatory activity of curcumin reduces inflammation with phenylbutazone to patients who have undergone surgery or suffered from trauma (Satoskar et al., 1986), reduce inflammation in arthritis, enhances wound healing. Antioxidant property of curcumin inhibit generation of superoxide, formation and generation of free radicals (Sharma, 1976; Reddy and Lokesh, 1992; Subramonian et al., 1994; Ruby et al., 1995), prevention of lipid peroxidation (Sreejayan and Rao, 1994) and oxidative damage to the arterial wall and impose protection action against vascular dementia. About 500 mg of curcuminoids daily intake for 7 days reduces lipid peroxides by 33% and blood cholesterol by 29%, thereby reducing cardiovascular diseases (Soni and Kuttan, 1992). *(i) Antimutagenic and Anticancerous Action:* It prevents DNA damage (Polasa et al., 2004). *(ii) Anticoagulant Action:* It inhibits collagen and adrenaline-induced platelet aggregation and has anti-*Leishmania* activity, anti-*Plasmodium falciparum. (iii) Chemopreventive and Bioprotectant Action:* It has the capacity to intervene the initiation and growth of cancer cells and tumours by preventing the spread throughout the body and increases cancer cells' sensitivity to certain drugs commonly used to combat cancer, rendering chemotherapy (Stoner and Mukhtar, 1995, Khafif et al., 1998; Kawamori et al., 1999; Bush et al., 2001; Jung et al., 2005). By inhibiting the UVB radiated damage it reduces the incidence of skin cancer. Curcumin has anti-HIV effect (Li et al., 1993; Lin et al., 1994). HIV infection is characterized by a complex command system, the structural part i.e. 'long terminal repeat' (LTR), which results in virus activation or inactivation. Drugs that interfere with LTR may be of potential therapeutic value in delaying active HIV infection and the progression of AIDS. Curcumin inhibit activation of the LTR and to decrease HIV replication effectively. *(iv) Antimicrobial Action:* Curcuminoids, inhibit the growth of numerous gram-positive and gram-negative bacteria, fungi and intestinal parasite, *Entamoeba histolytic* (Dhar et al., 1968)*, Staphylococcus aureus* (Bhavani Shankar and Srinivasamurthy, 1979) and inhibits in vitro production of aflatoxins produced by the mold *A. parasiticus*. Antibacterial and antiviral activities of curcumin can be enhanced significantly by illumination with visible light (Dahl et al., 1989). *(v) Antiprotozoal Action:* Curcumin has anti-Leishmania, anti-Plasmodium falciparum, and anti-L.major activity and synthetic derivatives have anti-L. amazonensis effect. *(vi) Antidiabetic Action:* Dietary curcumin (hypolipidemic agent) can alleviate dangerous secondary complications induced by diabetes (Babu and Srinivasan, 1997). It has higher rate of cholesterol catabolism. Curcumin inhibit the growth of B-lymphomas, prevent DNA damage, poses anti-cancer properties, including anti-proliferation, anti-invasion, and anti-angiogenesis, antispasmodic activity, may serve as a potential preventive or therapeutic agent for colorectal cancer, and regulate diabetes induced malfunctions by preventing or treating CNS complications. It is effective in formalin-induced arthritis, reduces intestinal gas formation and carbon tetrachloride and D-galactosamine-induced glutamate oxaloacetate transaminase, glutamate pyruvate transaminase levels, and shows antitumor, anticarcinogenic activities. Curcumin binds with egg and soy-phosphatidylcholine, which in turn binds divalent metal ions to offer antioxidant activity. *Adverse Effect:* High dose of turmeric or prolonged use can cause gastrointestinal irritation, mild giddiness, epigastric burning in duodenal ulcer patient. Too many turmeric capsules may increase body temperature. *Dosage:* Turmeric should be taken as a powdered rhizome or a 1:1 liquid extract (prepared by 45% ethanol). For adults age 18 and older, usual doses range from 1.5 to 3 g/d of turmeric

root in divided doses. Average intake in the Indian population is 2–2.5 g daily (60–200 mg curcumin). It can cause contact dermatitis occupational exposure.

Common Unit Operations for Spices

The common unit operations for spices may be classified as, (i) Grinding, (ii) Extraction, and (iii) Encapsulation.

Grinding

Size reduction facilitates the nutrients to easily absorb in the living matter of the body. To make prepared food stuff more acceptable or delicious, it is required that the food must be cooked with spice which is composed of impervious coating and hence, must be ground thoroughly to give the food stuff a certain degree of acceptability. The fat in spices generally poses extra problems and is an important consideration in grinding. Most spices have their characteristics aroma and therefore their true value as spices is due to enclosed essential oils that constitute the ingredient of spice. Essential oils are metabolic substances which are not recycled in the metabolic process. These essential oils are present in the cells which in most cases can only be obtained after crushing. This is the reason why almost all spices are marketed in a ground state. Grinding is the process of size reduction of any substances subjecting to mechanical forces. The practical fracture occurs with the failure of internal molecular binding forces with respect to external forces. Size reduction machines operate on compression, impact, cutting, shearing or combinations of these techniques. Brittle material can be easily reduced by compression and impact, whereas tough material requires combined action of impact, cutting, and shearing. Soft material (with Mohs hardness, 1–4) can be reduced by cutting and shearing and, under certain conditions, by compression and impact. Such material typically behaves like a tough liquid during size reduction, which disperses material, agglomerates, opens the material's inner cell structures, and homogenizes the material. The mechanism (or combination of mechanisms) best suited to reducing material depends on the components' characteristics, and the desired final results. Table 11 shows the different types of grinding mechanism and machinery applications. The selection of appropriate size reduction machine requires the understanding of machine's parameters (grinding tools shape, size, sharpness, clearance, and screen opening size, etc.) and material characteristics (type, size, shape, hardness, etc.,). Table 12 deals with the physical, mechanical, and thermal properties of few spices. The general considerations of any size reduction machines can be given as follows:

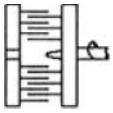
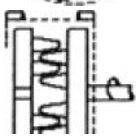
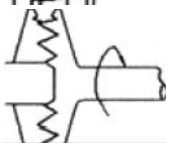
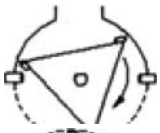
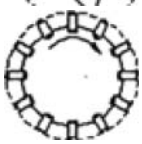
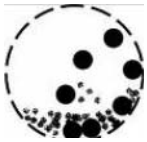
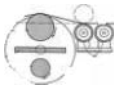
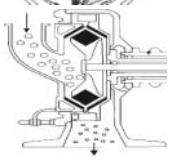
- Rotor: One or two rotors rotating parallel or coaxial.
- Axle direction: Horizontal, vertical, or angled inside the machine.
- Material inlet: Central or periphery of the rotor.
- Material flow: Radial direction (outward from the machine center), axial direction (along the machine axis), or peripheral direction (around the machine perimeter).
- Grinding tools: Hammers (fixed or movable), pins, plates, knives, cams, or grinding segments.
- Fineness control: Internal or external components for controlling the final particle fineness, including an adjustable grinding gap between the rotor and stator or a grate, screen, or classifier.

Grinding conditions may be broadly classified as (a) ambient and (b) cryogenic grinding.

(a) **Ambient condition:** In any grinding processes, heat is generated when energy is used to fracture a particle into a smaller size (Wistreich and Schafer, 1962) and found detrimental to heat sensitive materials such as spices and results in its loss in quality (Andres, 1976; Pesek and Wilson, 1986). During grinding, the temperature of the product rises to a level in the range of 42–95°C (Pruthi and Misra, 1963), which varies with the oil and moisture content of the spices, but spices lose a significant fraction of their volatile oil or flavoring components due to this temperature rise. The temperature rise of the product can be minimized to some extent by circulating cold air or water around the grinder. But this technique is not sufficient to significantly reduce the temperature rise of the product.

(b) **Cryogenic condition:** The cryogenic process actually embrittle a material prior to size reduction and controls heat buildup in the grinding equipment. Cryogenic grinding involves cooling of a material below its embitterment temperature with a cryogenic fluid, typically liquid nitrogen or, in certain applications, carbon dioxide. Generally, cryogenic grinding system for spices consists of screw conveyor assembly, compressor, liquid nitrogen dewar, power transmission system, and a grinder. The precooler consists of a screw assembly enclosed in a properly insulated barrel with a system for liquid nitrogen circulation. Precooling of the raw spice and the continuous low temperature maintained within the mill reduces the loss of volatile oils and moisture thereby retaining most of the flavor strength per unit mass of spice. After cooling, the material is fed into a mill where it is reduced in size primarily by brittle fracture. However, literatures available are very scarce regarding the design parameters of cryogenic grinders for spices and a proper distribution of liquid nitrogen both for precooler and grinder with cost reduction are need of the hour, and yet has to be designed. Pesek and Wilson (1986) reported that the cryogenically ground spices are superior in terms of increased volatile oil contents and flavor components and better color retention compared to those ground in traditional mill. Wilczek et al. (2004) discussed the effect of low temperatures on many materials to become brittle to facilitate and improve the efficacy of grinding. Cryogenic grinding proved to be effective process for fast sample

Table 11 Typical size reduction machinery

Type	Schematic	Size reduction mechanism	Peripheral speed (ms^{-1})	Typical applications
Pin and disc mill		Impact	80–160	Starch, sugar, caffeine, legumes, yeast, potato flakes, milk powder, spices, urea, pigments, hard waxes
Wing beater Mill		Impact and Shear	50–70	Alginates, pepper, pectin, paprika, dried vegetables
Disc Beater Mill		Impact and Shear	70–90	Milk powder, lactose, cereals, dried whey
Vertical toothed mill		Shear	4–8	Frozen coffee extract, plastic material, coarse grinding of rye, maize, wheat, fennel, pepper, etc.
Cutting granulator		Impact and Shear	5–18	Fish meal, pectin, dry fruits and vegetables
Hammer mill		Impact	40–50	Sugar, tapioca, dry vegetables, extracted bones, dried mills, spices, etc
Ball mill		Impact and Shear	–	Food colors
Roller mills		Compression and shear	1–8	Sugar cane, wheat, chocolate refining, etc.
Knife mill Granulator		Cutting	5–20	Cutting and disintegrating tea leaves, cheese, asparagus, leaf, bark, and root-based drugs, resin blocks, rubber bales
Turbo Mill		Impact, shearing and Cutting	80–120	Grinding and pulverizing or fiberizing and disintegrating oil seeds, fat, nuts, milk powder, flax meal, corn, cacao beans, salt, paper, organic and inorganic pigments

Source: Balasubramanian et al. (2012).

particle size reduction than traditional grinding (Table 13). Pruthi (1980) requested thus the loss of volatile oil can be significantly reduced by cryogenic grinding technology. Singh and Goswami (1999a, 1999b) studied the effect of cryogenic temperatures on volatile oil content of cumin seed and clove and reported the significance of cryogenic grinding and the quality of ground samples. Manohar and Sridhar (2001) reported the effect of cryogenic grinding on particle size distribution of turmeric and confirmed the usefulness of cryogrinding process for heat-sensitiveness. Studies conducted by Jacob et al. (2000) clearly indicated that the quality of the end-product (cryogenically ground) was superior.

Extraction

Essential oils are the volatile fraction of the secondary metabolites produced by plants. Essential oil-bearing plants

Table 12 Some properties of selected seed spices at different moisture content (5–25%, db)

Properties	Black Pepper	Coriander	Fenugreek
	Physical properties		
	Dimension (mm)		
Major	4.94–5.62	4.10–3.74	4.01–4.36
Medium	4.63–5.33	3.20–3.93	2.42–2.89
Minor	4.45–5.15	2.92–3.52	1.48–1.95
Geometric mean diameter (mm)	4.67–5.37	3.36–3.80	2.43–2.90
Sphericity (%)	94–95	82–95	60–66
Bulk density (kg/m^3)	555–536	291–286	850–740
Porosity (%)	44–48		32–41
1000 seed wt (g)	44–61	8.6–8.3	13–15
	Mechanical Properties		
Rupture force (N)	74.12–25.34	8.38–3.52	214.62–73.36
Energy absorbed (kJ)	43.78–16.71	6.58–4.07	302.72–122.40
Angle of Repose (°)	23–39	23–38	14–21
	Coefficient of friction		
Plywood	0.874–0.968	0.945–0.965	0.553–0.809
MS Sheet	0.857–0.957	0.822–0.960	0.533–0.779
GI Sheet	0.737–0.853	0.808–0.966	0.515–0.787
Aluminum	0.711–0.853	0.728–0.890	0.491–0.705
	Thermal properties		
Thermal conductivity (W/m-K)	0.119–0.184	0.088–0.134	0.131–0.163

have been valued historically for their medicinal, culinary, and fragrance properties. However, the essential oils are highly complex and may include oxygenated compounds (alcohols, aldehydes, ketones, acids, phenols, oxides, lactones, acetals, ethers, and esters) apart from pure hydrocarbons; and also at times, trace of potentially harmful nitrogen containing compounds. There are five common methods of extraction viz., include expression, hydro- or water-distillation, water and steam distillation, steam distillation and solvent extraction. In this review, only the solvent extraction (super critical fluid) is explained in detail. Supercritical fluid extraction (SFE) is the most versatile separation technology now being employed. Supercritical CO_2 is an ideal solvent for extraction, because it is cheap, abundant, inert, nontoxic, noncorrosive, noninflammable and does not pollute the environment. The quality of the product is high compared to conventional extraction process. It has high extraction selectivity from a mixture of components because of the pressure-temperature-dependent solubility in the solvents. These conditions lower the solubility of the spice raw materials in the solvent. When the material starts to separate, the gas is again compressed back to extract the material.

Table 13 Comparison of traditional and cryogenic grinding

Parameter	Traditional Grinding	Cryogenic grinding
Energy Consumption	High	Low
Throughput	Low	High
Mill Clogging	Frequent	No Clogging
Volatile Losses	Higher	Minimum
Motor Capacity	High	Low
Control on particle size	No control	Effective
Grinding of soft material	Very difficult	Possible
Fire Risk^{++}	High	No
Air Pollution^{+++}	Yes	No
Microbial Load^{+++}	Possible	Does not exist

Source: $^{+}$Singh and Goswami (1999a, 1999b, 2000), Murthy and Bhattacharya (2008); $^{++}$Manish and Goswami (2003), $^{+++}$http://spectracryogenic.tradeindia. com.

Microencapsulation

Various researches has reported the different methods of extraction (subcritical water extraction, hydro distillation and solvent extraction, supercritical fluid extraction etc.) application in spices (coriander, pepper, and cinnamon) and developed its compounds and comparisons among methods (Saim, et al., 2008). Generally microencapsulation is the process of entrapping component of interest (vitamins, protein, flavor etc.) with a protective thin (μm) layer of polysaccharide, lipid or protein material to reduce the encapsulated capsules in the processing system. This technique protects and stabilizes sensitive ingredients (flavor, oil, nutraceuticals etc.,) which have limited stability and need careful handling to maintain their functionality and to achieve desire shelf life. Microencapsulation methods include coating/agglomeration, emulsion, micro emulsion, spraying, coacervation, polymerization etc. Spice, essential oils are one of the most relevant raw materials for perfume and pharmaceutical industries, the molecular encapsulation of essential oils upgrades their chemical and thermal stability and facilitates handling which could increase the potential uses in new dosage forms (Reineccius and Peppard, 2002; Fernandes et al., 2004). But, a proper balance of the encapsulated flavor volatiles in the final

complex powder is of great importance. Alginate and chitosan are two naturally occurring biopolymers that are used for the encapsulation of flavor components. Many sophisticated technologies are available for encapsulation of complex mixtures of biopolymers as well as low molecular weight surfactants, and novel multilayered interfacial structures (Peter and Given, 2009). Kshirsagar et al., (2007); Goran et al., (2010); Shaikh et al., (2006) has microencapsulated the turmeric oleoresin, cinnamon oil in β-cyclodextrin by co-precipitation method, black pepper oleoresin by spray-drying, using gum arabic and modified starch as wall materials, respectively.

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