Woodhead Publishing in Food Science and Technology

Handbook of herbs and spices

Edited by K. V. Peter

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Herbs and spices are among the most versatile and widely used ingredients in food processing. As well as their traditional role in flavouring and colouring foods, they have increasingly been used as natural preservatives and for their potential health-promoting properties, for example as antioxidants. Edited by a leading authority in the field, and with a distinguished international team of contributors, the *Handbook of herbs and spices* provides an essential reference for manufacturers wishing to make the most of these important ingredients.

A first group of chapters looks at general issues including quality indices for both conventional and organically-produced herbs, spices and their essential oils. However, the main body of the handbook consists of over twenty chapters covering key spices and herbs from aniseed, bay leaves and black pepper to saffron, tamarind and turmeric. Chapters cover key issues from definition and classification to chemical structure, cultivation and post-harvest processing, uses in food processing, functional properties, regulatory issues, quality indices and methods of analysis.

The *Handbook of herbs and spices* will be a standard reference for all manufacturers using herbs and spices in their products.

Professor K. V. Peter is Director of Research at Kerala Agricultural University. He was formerly Director of the Indian Institute of Spices Research, Calicut where he conducted ground-breaking research on such spices as black pepper and cardamom.

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Handbook of herbs and spices

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1

Introduction

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1.1 Definitions

The Geneva-based International Standards Organisation (ISO) defines spices and condiments as:

> Vegetable products or mixtures thereof, free from extraneous matter, used for flavouring, seasoning and imparting aroma in foods.

Webster describes spices as:

> Any of various aromatic vegetable productions as pepper, cinnamon, nutmeg, mace, allspice, ginger, cloves, etc., used in cookery to season and to flavour sauces, pickles, etc.; a vegetable condiment or relish, usually in the form of a powder; also, as condiments collectively.

The famous spice author Rosengarten describes a spice as a product which enriches or alters the quality of a thing, for example altering the taste of a food to give it zest or pungency; a piquant or lasting flavouring; or a relish. The term 'spice' is thus used to cover the use of spices, herbs and certain aromatic vegetables to impart odour and flavour to foods. The taxonomic classification of spices is shown in Table 1.1. A conventional classification of spices is based on degree of taste as:

- hot spices
- mild spices
- aromatic spices
- herbs and aromatic vegetables

This classification is shown in Table 1.2. Though the term spice can be used to incorporate herbs, the distinction between herbs and spices can be described as follows:

- Herbs may be defined as the dried leaves of aromatic plants used to impart flavour and odour to foods with, sometimes, the addition of colour. The leaves are commonly traded separately from the plant stems and leaf stalks.

Table 1.1 Taxonomic classification of spices

Angiospermae	Dicotyledoneae	Sympetalae			
				Solanaceae	chilli, paprika, red pepper
				Pedaliaceae	sesame
			Campalunatae	*Compositae*	camomile, chicory, tarragon
		Archichlamydaeae	Piperales	*Piperaceae*	cubeba, long pepper, pepper
			Ranales	*Myristicaceae*	mace, nutmeg
				Lauraceae	bay leaf, cassia, cinnamon
				Magnoliaceae	star-anise
			Rhoeadales	*Cruciferae*	mustard, wasabi
			Myrtiflorae	*Myrtaceae*	allspice, clove
			Umbelliflorae	*Umbelliferae*	anise, caraway, celery, chervil, coriander, cumin, dill, fennel, parsley
	Monocotyledoneae		Liliiflorae	*Liliaceae*	garlic, onion
				Iridaceae	saffron
			Scitamineae	*Zingiberaceae*	cardamom, ginger, turmeric
			Orchidales	*Orchidaceae*	vanilla

- Spices may be defined as the dried parts of aromatic plants with the exception of the leaves. This definition is wide-ranging and covers virtually all parts of the plant.

The various parts of plants used to produce the range of herbs and spices are illustrated in Table 1.3. Herbs and spices have been used in foods since antiquity. ISO document 676 lists 109 herb and spice plant species useful as ingredients in food. These are shown in Appendix 1 at the end of this chapter.

Table 1.2 Conventional classification of spices

Classes	Spices
Hot spices	Capsicum (chillies), Cayenne pepper, black and white peppers, ginger, mustard
Mild spices	Paprika, coriander
Aromatic spices	Allspice (pimento), cardamom, cassia, cinnamon, clove, cumin, dill, fennel, fenugreek, mace and nutmeg
Herbs	Basil, bay, dill leaves, marjoram, tarragon, thyme
Aromatic vegetables	Onion, garlic, shallot, celery

Table 1.3 Plant organs as spices

Plant organs	Spice crops
Aril	Mace of nutmeg
Barks	Cassia, cinnamon
Berries	Allspice, black pepper, chilli
Buds	Clove
Bulbs	Onion, garlic, leek
Pistil (female part of flower)	Saffron
Kernel	Nutmeg
Leaf	Basil, bay leaf, mint, marjoram, sage, curry leaf
Rhizome	Ginger, turmeric
Latex from rhizome	Asafoetida
Roots	Angelica, horse-radish
Seeds	Ajowan, aniseed, caraway, celery, coriander, dill, fennel, fenugreek, mustard, poppy seed

1.2 The trade in spices

Some of the main spice-producing areas are listed in Appendix 2 at the end of this chapter. The current annual global trade in spices is 6–7 lakh tonnes valued at US$3–3.5 billion. The value of the spice trade is particularly dependent on pepper prices as pepper remains the main spice in international trade. The global spice trade is expected to increase with the growing consumer demand in importing countries for more exotic, ethnic tastes in food. In the UK, for example, spice imports have increased by 27% in the last five years, mainly through the growth in cinnamon, cloves, garlic and seed spices. About 85% of spices are traded internationally in whole form, with importing countries processing and packaging the final product for the food industry and the retail market. The trade in processed and value-added spice ingredients is, however, growing rapidly as importers look for cheaper global sourcing of spice products and exporting businesses develop the appropriate technologies and quality systems. There is limited competition from synthetic products, with the exception of vanilla, particularly given consumer preferences for 'natural' ingredients in food products.

The USA is the biggest importer of spice products, followed by Germany and Japan. The European Union has the largest imports of spices in value terms, worth US$2.2 billion and consisting of:

- 44% retail sales to consumers
- 41% sales to the food manufacturing sector
- 15% to the catering sector

A snapshot of the nature of the European spices market is provided by France. The total consumption of spices in 1993 was 16,545 tonnes (with a per capita consumption of 290 grams), of which more than 50% was black pepper. The main market is the retail sector with over 100 million consumer packs of spices sold in 1993, valued at US$150 million. The catering market in 1993 was worth US$20–25 million. Other major importing regions are the Middle East and North Africa, whilst there are growing markets in other countries. In South Africa, for example, the annual spice trade is worth US$94 million, but is set to grow as consumers demand more exotic tastes in food.

1.3 Spice flavours

Important flavour compounds found in culinary herbs and other spice plants are:

- eugenol (allspice, cinnamon, cassia, clove)
- piperine (black pepper)
- gingerol (ginger)
- myristicin (nutmeg)
- turmerone (turmeric)
- vanillin (vanilla).

The main flavour compounds found in the major herbs and spices used by the food industry are summarised in Tables 1.4 and 1.5. In using spices to flavour foods, the aim should always be to arrive at a balanced overall odour and flavour effect, complementing and accentuating, rather than swamping, the flavour of the basic ingredients, and usually without any single spice predominating excessively. This culinary art needs experience and expertise and in-house training with the assistance of leading spice houses.

1.4 Processing issues

Spices can be added to foods in several forms: as whole spices, as ground spices, as essential oils, as oleoresins or as prepared and filtered vinegar infusions. A more recent alternative is spice extracts. These consist of the flavour components of a spice, dispersed on one of several types of base, the most suitable bases for pickle and sauce use, for example, being salt or dextrose. Natural materials used in flavour creations are still most often isolated from essential oils. Extraction of oils and oleoresins is accomplished using a range of methods, including:

Table 1.4 Important flavour compounds in spices

Spice	Important flavour compounds
Allspice	Eugenol, β-caryophyllene
Anise	(E)-anethole, methyl chavicol
Black pepper	Piperine, S-3-Carene, β-caryophyllene
Caraway	d-carvone, carone derivatives
Cardamom	α-terpinyl acetate, 1-8-cineole, linalool
Cinnamon, cassia	Cinnamaldehyde, eugenol
Chilli	Capsaicin, dihydro capsaicin
Clove	Eugenol, eugeneyl acetate
Coriander	d-linalool, C10-C14-2-alkenals
Cumin	Cuminaldehyde, p-1,3-mentha-dienal
Dill	d-carvone
Fennel	(E)-anethole, fenchone
Ginger	Gingerol, Shogaol, neral, geranial
Mace	α-pinene, sabinene, 1-terpenin-4-ol.
Mustard	Ally isothiocynate
Nutmeg	Sabinine, α-pinene, myristicin
Parsley	Apiol
Saffron	Safranol
Turmeric	Turmerone, Zingeberene, 1,8-cineole
Vanilla	Vanillin, p-OH-benzyl-methyl ether

Table 1.5 Important flavour compounds in a few culinary herbal spices

Herbal spices	Flavour compounds
Basil, Sweet	Methylchavicol, linalool, methyl eugenol
Bay laurel	1,8-cineole
Marjoram	e- and t-sabinene hydrates, terpinen-4-ol
Oregano	Carvacrol, thymol
Origanum	Thymol, carvacrol
Rosemary	Verbenone, 1-8-cineole, camphor, linanool
Sage, Clary	Salvial-4 (14)-en-1-one, linalool
Sage, Dalmation	Thujone, 1,8-cineole, camphor
Sage, Spanish	e- and t-sabinylacetate, 1,8-cineole, camphor
Savory	Carvacrol
Tarragon	Methyl chavicol, anethole
Thyme	Thymol, carvacrol
Peppermint	1-menthol, menthone, menthfuran
Spear mint	1-carvone, carvone derivatives

- steam distillation
- hydrocarbon extraction
- chlorinated solvent extraction
- enzymatic treatment and fermentation
- super critical carbon dioxide extraction.

Carbon dioxide extraction from solid botanicals is now on a commercial scale. The advantages of the resulting essential oils are no solvent residue, less terpenes and enhanced black notes. Enzymatic treatment and fermentation of raw botanicals also result in greater yields and quality of essential oil. More recently, the use of genetic engineering and recombinant DNA on the bacteria and fungi used in fermentation has resulted in natural esters, ketones and other flavouring materials 'made to order'. Cloning and single cell culture techniques are of benefit to the flavourist, for example in cultivating flavour cells from black pepper, cardamom or thyme instead of growing the entire plant. *In vitro* synthesis of secondary metabolites may, in the future, lower market prices of traditionally-cultivated spices.

There have also been improvements in preservation technologies to ensure that raw spices in particular are free of microbial and other contamination and that their shelf-life is extended. Techniques include osmotic dehyration and storage within a medium such as high fructose corn syrup. With the banning of chemical treatments such as ethylene oxide in treating microbial contamination, irradiation has grown in popularity, with an estimated 25,000 tonnes of raw spices currently irradiated each year to counter both insect and microbial contamination. Countries with commercial-scale irradiation operations for herbs and spices include: the USA, Canada, The Netherlands, Belgium, France, Denmark, Finland, Israel, Iran, the Republic of Korea, Vietnam, South Africa and a number of Eastern European countries.

1.5 The functional role of spices

Herbs and spices are not just valuable in adding flavour to foods. Their antioxidant activity also helps to preserve foods from oxidative deterioration, increasing their shelf-

Table 1.6 Antioxidants isolated from herbs and spices

Spices and herbs	Systematic names	Substances and type of substances
Rosemary	*Rosemarinus officinalis*	Carnosic acid, carnosol, rosemarinic acid, rosmanol
Sage	*Salvia officinalis*	Carnosol, carnosic acid, rosmanol, rosmarinic acid
Oregano	*Origanum vulgare*	Derivatives of phenolic acids, flavonoids, tocopherols
Thyme	*Thymus vulgaris*	Thymol, carvacrol, p-cunene-2,3-diol, biphehyls, flavonoids
Ginger	*Zingiber officinale*	Gingerol-related compounds, diarylheptanoids
Turmeric	*Curcuma domestica*	Curcumins
Summer savory	*Satureja hortensis*	Rosemarinic acid, carnosol, carvacrol, thymol
Black pepper	*Piper nigrum*	Phenolic amides, flavonides
Red pepper	*Capsicum annum*	Capsaicin
Chilli pepper	*Capsicum frutescence*	Capsaicin, capsaicinol
Clove	*Eugenia caryophyllata*	Eugenol, gallates
Marjoram	*Marjorana hortensis*	Flavonoids
Common balm	*Melissa officinalis*	Flavonoids
Licorice	*Glycyrrhiza glabra*	Flavonoids, licorice phenolics

life. There has been increasing research in the role of herbs and spices as natural preservatives. As an example, ground black pepper has been found to reduce the lipid oxidation of cooked pork. Table 1.6 illustrates the range of antioxidants isolated from herbs and spices. Antioxidants also play a role in the body's defence against cardiovascular disease, certain (epithelial) cancers and other conditions such as arthritis and asthma. Phenolic compounds such as flavonoids may help to protect against cardiovascular disease and intestinal cancer (black pepper, oregano, thyme and marjoram). Gingerol in ginger is also an intestinal stimulant and promoter of the bioactivity of drugs. Capsaicin in chilli pepper is an effective counter-irritant used in both pharmaceuticals and cosmetics. Fenugreek, onion and garlic help lower cholesterol levels. A number of spices have also been identified as having antimicrobial properties. Individual chapters in this book deal with research on the functional role of particular spices.

1.6 The structure of this book

This book covers a number of general issues such as quality. However, it consists mainly of coverage of individual spices and herbs. Contributors were asked to follow a common format:

- introduction: dealing with issues of definition and classification. Such issues can be very significant in establishing appropriate standards of quality and authenticity
- chemical structure: essential in assessing such issues as quality, potential applications and processing functionality
- production: a description of the principal methods of cultivation and post-harvest processing which have a significant impact on quality and functionality

- uses in food processing: a review of current and potential applications
- functional properties: as has already been noted, there is increasing interest in herbs and spices as functional ingredients, for example as natural antioxidants. Where appropriate, contributors summarise the current state of research on the nutritional and functional benefits of individual spices and herbs. Issues of toxicity and allergy are also addressed where necessary
- quality and regulatory issues: a summary of the key quality standards and indices relating to the herb and spice.

Individual chapters vary in structure and emphasis, depending on the nature of the spice in question and the particular issues and body of research surrounding it. It is hoped that the book will help food manufacturers and others to make even fuller use of the valuable resource that herbs and spices provide.

1.7 Sources of further information and advice

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Appendix 1: ISO list of plant species

No.	Botanical name of the plant	Family	Common name	Name of plant part used as spice
1.	Acorus calamus	Araceae	Sweet flag, myrtle flag, calamus, flag root	Rhizome
2.	Aframomum angustifolium	Zingiberaceae	Madagascar cardamom	Fruit, seed
3.	Aframomum hanburyi	Zingiberaceae	Cameroon cardamom	Fruit, seed
4.	Aframomum koranima	Zingiberaceae	Korarima cardamom	Fruit, seed
5.	Aframomum melegueta	Zingiberaceae	Grain of paradise, Guinea grains	Fruit, seed
6.	Allium ascalonicum	Liliaceae	Shallot	Bulb
7.	Allium cepa	Liliaceae	Onion	Bulb
8.	Allium cepa var. aggregatum	Liliaceae	Potato onion	Bulb
9.	Allium tuberosum	Liliaceae	Indian leek, Chinese chive	Bulb, leaf
10.	Allium fistulosum	Liliaceae	Stony leek, Welsh onion, Japanese bunching onion	Leaf and bulb
11.	Allium porrum	Liliaceae	Leek, winter leek	Leaf and bulb
12.	Allium sativum	Liliaceaee	Garlic	Bulb
13.	Allium schoenoprasum	Liliaceae	Chive	Leaf
14.	Alpinia galanga	Zingiberaceae	Greater galangal, Longwas, Siamese ginger	Rhizome
15.	Alpinia officinarum	Zingiberaceae	Lesser galangal	Rhizome
16.	Amomum aromaticum	Zingiberaceae	Bengal cardamom	Fruit, seed
17.	Amomum kepulaga	Zingiberaceae	Round cardamom, Chester cardamom, Siamese cardamom, Indonesian cardamom	Fruit, seed
18.	Amomum krervanh	Zingiberaceae	Cambodian cardamom	Fruit, seed
19.	Amomum subulatum	Zingiberaceae	Greater Indian cardamom, large cardamom, Nepalese cardamom	Fruit, seed
20.	Amomum tsao-ko	Zingiberaceae	Tsao-ko cardamom	Fruit, seed
21.	Anethum graveolens	Apiaceae (Umbelliferae)	Dill	Fruit, leaf, top
22.	Anethum sowa	Apiaceae (Umbelliferae)	Indian dill	Fruit
23.	Angelica archangelica	Apiaceae (Umbelliferae)	Garden angelica	Fruit, petiole
24.	Anthriscus cereifolium	Apiaceae (Umbelliferae)	Chervil	Leaf
25.	Apium graveolens	Apiaceae (Umbelliferae)	Celery, garden celery	Fruit, root, leaf
26.	Apium graveolens var. rapaceum	Apiaceae (Umbelliferae)	Celeriac	Fruit, root, leaf
27.	Armoracia rusticana	Brassicaceae (Cruciferae)	Horse radish	Root

No.	Botanical name of the plant	Family	Common name	Name of plant part used as spice
28.	Artemisia dracunculus	Asteraceae (Compositae)	Tarragon, estragon	Leaf
29.	Averrhoa bilimbi	Averrhoaceae	Belimbing, bilimbi cucumber tree	Fruit
30.	Averrhoa carambola	Averrhoaceae	Carambola, caramba	Fruit
31.	Brassica junceae	Brassicaceae	Indian mustard	Seed
32.	Brassica nigra	Brassicaceae	Black mustard	Seed
33.	Bunium persicum	Apiaceae (Umbelliferae)	Black caraway	Seed, tuber
34.	Capparis spinosa	Capparidaceae	Caper, common caper, caper bush	Floral bud
35.	Capsicum annuum	Solanaceae	Capsicum, chillies, paprika	Fruit
36.	Capsicum frutescens	Solanaceae	Chillies, bird's eye chilli	Fruit
37.	Carum bulbocastanum	Apiaceae (Umbelliferae)	Black caraway	Fruit, bulb
38.	Carum carvi	Apiaceae (Umbelliferae)	Caraway, blond caraway	Fruit
39.	Cinnamomum aromaticum	Lauracea	Cassia, Chinese cassia	Bark, leaves
40.	Cinnamomum burmanii	Lauraceae	Indonesian cassia	Bark
41.	Cinnamomum loureirii	Lauraceae	Vietnamese cassia	Bark
42.	Cinnamomum tamala	Lauraceae	Tejpat, Indian cassia	Leaf, bark
43.	Cinnamomum zeylanicum	Lauraceae	Sri Lankan cinnamon, Indian cinnamon	Bark, leaf
44.	Coriandrum sativum	Apiaceae (Umbelliferae)	Coriander	Leaf, fruit
45.	Crocus sativus	Iridaceae	Saffron	Stigma
46.	Cuminum cyminum	Apiaceae (Umbelliferae)	Cumin	Fruit
47.	Curcuma longa	Zingiberaceae	Turmeric	Rhizome, leaf
48.	Cymbopogon citratus	Poaceae	West Indian lemongrass	Leaf
49.	Cymbopogon nardus	Poaceae	Sri Lankan citronella	Leaf
50.	Elettaria cardamomum	Zingiberaceae	Small cardamom	Fruit, seed
51.	Elettaria cardamomum	Zingiberaceae	Sri Lankan cardamom	Fruit, seed
52.1	Ferula assa-foetida	Apiaceae (Umbelliferae)	Asafoetida	Rhizome
52.2	Ferula foetida			
52.3	Ferula narthex			
53.	Foeniculum vulgare	Apiaceae	Bitter fennel	Leaf, twig, fruit
54.	Foeniculum vulgare	Apiaceae	Sweet fennel	Leaf, twig, fruit
55.	Garcinia cambogia	Clusiaceae	Garcinia, Camboge	Pericarp of the fruit
56.	Garcinia indica	Clusiaceae	Garcinia, Kokum	Pericarp of the fruit

No.	Botanical name of the plant	Family	Common name	Name of plant part used as spice
57.	Hyssopus officinalis	Lamiaceae	Hyssop	Leaf
58.	Illicum verum	Illiciaceae	Star anise, Chinese anise	Fruit
59.	Juniperus communis	Cupressaceae	Common juniper	Fruit
60.	Kaempferia galanga	Zingiberaceae	Galangal	Rhizome
61.	Laurus nobilis	Lauraceae	Laurel, true laurel, bay leaf, sweet flag	Leaf
62.	Levisticum officinale	Apiaceae	Garden lovage, lovage	Fruit, leaf
63.1	Lippia graveolens	Verbenaceae	Mexican oregano	Leaf, terminal shoot
63.2	Lippia berlandieri			
64.	Mangifera indica	Anacardiaceae	Mango	Immature fruit (rind)
65.	Melissa officinalis	Lamiaceae	Balm, lemon balm, melissa	Leaf, terminal shoot
66.	Mentha arvensis	Lamiaceae	Japanese mint, field mint, corn mint	Leaf, terminal shoot
67.	Mentha citrata	Lamiaceae	Bergamot	Leaf, terminal shoot
68.	Mentha x piperita	Lamiaceae	Peppermint	Leaf, terminal shoot
69.	Mentha spicata	Lamiaceae	Spearmint, garden mint	Leaf, terminal shoot
70.	Murraya koenigii	Rutaceae	Curry leaf	Leaf
71.	Myristica argentea	Myristicaceae	Papuan nutmeg Papuan mace	Kernel Aril
72.	Myristica fragrans	Myristicaceae	Indonesian type nutmeg, Indonesian type mace, Siauw type mace	Kernel Aril
73.	Nigella damascena	Ranunculaceae	Damas black cumin, love in a mist	Seed
74.	Nigella sativa	Ranunculaceae	Black cumin	Seed
75.	Ocimum basilicum	Lamiaceae	Sweet basil	Leaf, terminal shoot
76.	Origanum majorana	Lamiaceae	Sweet marjoram	Leaf, floral bud
77.	Origanum vulgare	Lamiaceae	Oregano, origan	Leaf, flower
78.	Pandanus amaryllifolius	Pandanaceae	Pandan wangi	Leaf
79.	Papaver somniferum	Papaveraceae	Poppy, blue maw, mawseed	Seed
80.	Petroselinum crispum	Apiceae	Parsley	Leaf, root
81.	Pimenta dioica	Myrtaceae	Pimento, allspice, Jamaica pepper	Immature fruit, leaf
82.	Pimenta racemosa	Myrtaceae	West Indian bay	Fruit, leaf
83.	Pimpinella anisum	Apiaceae	Aniseed	Fruit
84.	Piper guineense	Piperaceae	West African or Benin pepper	Fruit
85.	Piper longum	Piperaceae	Long pepper, Indian long pepper	Fruit
86.	Piper nigrum	Piperaceae	Black pepper, white pepper, green pepper	Fruit

No.	Botanical name of the plant	Family	Common name	Name of plant part used as spice
87.	Punica granatum	Punicaceae	Pomegranate	Seed (dried with flesh)
88.	Rosmarinus officinalis	Lamiaceae	Rosemary	Terminal shoot, leaf
89.	Salvia officinalis	Lamiaceae	Garden sage	Terminal shoot, leaf
90.	Satureja hortensis	Lamiaceae	Summer savory	Terminal shoot, leaf
91.	Satureja montana	Lamiaceae	Winter savory	Leaf, twig
92.	Schinus molle	Anacardiaceae	American pepper, Californian pepper tree	Fruit, wall (rind)
93.	Schinus terebenthifolius	Anacardiaceae	'Brazilian pepper'	Fruit
94.	Sesamum indicum	Pedaliaceae	Sesame, gingelly	Seed
95.	Sinapis alba	Brassicaceae	White mustard, yellow mustard	Seed
96.	Syzygium aromaticum	Myrtaceae	Clove	Flower bud
97.	Tamarindus indica	Cesalpiniaceae	Tamarind	Fruit
98.	Thymus serpyllum	Lamiaceae	Mother of thyme, wild thyme, creeping thyme	Terminal shoot, leaf
99.	Thymus vulgaris	Lamiaceae	Thyme, common thyme	Terminal shoot, leaf
100.	Trachyspermum ammi	Apiaceae	Ajowan	Fruit
101.	Trigonella Foenumgracecum	Fabaceae	Fenugreek	Seed, leaf
102.	Vanilla planifolia syn. Vanilla fragrans	Orchidaceae	Vanilla	Fruit (pod)
103.	Vanilla tahitensis	Orchidaceae	Vanilla	Fruit (pod)
104.	Vanilla pompona	Orchidaceae	Pompona vanilla	Fruit (pod)
105.	Xylopia aethiopica	Annonaceae	Negro pepper, Guinean pepper	Fruit
106.	Zanthoxylum bungei	Rutaceae	Chinese prickly ash pepper, Sechuang pepper	Fruit
107.	Zanthoxylum acanthopodium	Rutaceae	Chinese pepper	Fruit
108.	Zanthoxylum piperitum	Rutaceae	Japanese pepper	Fruit
109.	Zingiber officinale	Zingiberaceae	Ginger	Rhizome

Appendix 2: Major spice-producing areas

Spices	Edible part(s)	Major source/origin
Allspice	Berry, leaf	Jamaica, Mexico
Aniseed	Fruit	Mexico, The Netherlands, Spain
Basil, Sweet	Leaf	France, Hungary, USA, Yugoslavia
Caraway	Fruit	Denmark, Lebanon, The Netherlands, Poland
Cardamom	Fruit	India, Guatemala,
Celery	Fruit	France, India
Chervil	Leaf	USA
Chilli	Fruit	Ethiopia, India, Japan, Kenya, Mexico, Nigeria, Pakistan, Tanzania, USA
Cinnamon	Stem bark	Sri Lanka
Cassia	Stem bark	China, Indonesia, South Vietnam
Clove	Buds	Indonesia, Malaysia, Tanzania
Coriander	Fruit	Argentina, India, Morocco, Romania, Spain, Yugoslavia
Cumin	Fruit	India, Iran, Lebanon
Dill	Fruit	India
Fennel	Fruit	Argentina, Bulgaria, Germany, Greece, India, Lebanon
Fenugreek	Fruit	India
Garlic	Bulb/clove	Argentina
Ginger	Rhyzome	India, Jamaica, Nigeria, Sierra Leone
Laurel	Leaf	Portugal, Turkey
Marjoram (sweet)	Leaf	Chile, France, Lebanon, Mexico, Peru
Mint	Leaf, terminal shoot	Bulgaria, Egypt, France, Germany, Greece, Morocco, Romania, Russia, UK
Mustard	Seed	Canada, Denmark, Ethiopia, UK
Nutmeg	Aril, seed kernel	Grenada, Indonesia
Onion	Bulb	Argentina, Romania
Oregano	Leaf	Greece, Mexico
Paprika	Fruit	Bulgaria, Hungary, Morocco, Portugal, Spain, Yugoslavia
Parsley	Leaf	Belgium, Canada, France, Germany, Hungary
Black pepper	Fruit	Brazil, India, Indonesia, Malaysia, Sri Lanka
Poppy	Seed	The Netherlands, Poland, Romania, Turkey, Russia
Rosemary	Leaf, terminal shoot	France, Spain, USA, Yugoslavia
Saffron	Pistil of flower	Spain
Sage	Leaf	Albania, Yugoslavia
Sesame	Seed	China, El-Salvador, Ethiopia, Guatemala, India, Mexico, Nicaragua
Star anise	Fruit	China, North Vietnam
Tarragon	Leaf	France, USA
Thyme	Leaf	France, Spain
Turmeric	Rhizome	China, Honduras, India, Indonesia, Jamaica
Vanilla	Fruit/beans	Indonesia, Malagasy Republic, Mexico

Source: Mahindru, S.N. (1994). *S.N. Mahindru's Manual of Indian Spices.* Academic Foundation, New Delhi, p. 380.

2

Quality specifications for herbs and spices

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2.1 Defining quality

Within the herb and spice industry, the terms authenticity and quality are sometimes at odds. Authenticity can be defined as freedom from adulteration, most obviously in the sense of absence of foreign bodies or extraneous matter, but it also suggests freedom from impurities in the product itself. However, in practice authenticity is not always helpful in the case of herbs and spices. As an example, sage in virtually all textbooks is defined as *Salvia officinalis*. But there are some 300 species of sage and some of the major ones, which are traded throughout the world at present, are not the 'classic' *Salvia officinalis*. *Salvia trilobula* and *tomatosa* species are widely traded and these are accepted universally as sage. Similarly with thyme, references are usually to *Thymus vulgaris* but most thyme traded is a mixture of *Thymus capitatus*, *Thymus serpyllum* and *Thymus vulgaris*. This blend is universally accepted as thyme. Turning to examples of spices, turmeric is defined as *Curcuma longa*, but there are sub-species such as Alleppy turmeric, which is dark red orange in colour with a rough outer appearance to the root, whereas Cuddapah turmeric is lighter lemon yellow in colour with a smoother root. Each type has its own market niche. The reason for these variations is that most herbs and spices were originally wild rather than cultivated crops, gathered from their natural habitat where mixing of the species and sub-species occurred. A more appropriate term is quality which can be defined in the case of herbs and spices as 'fit (and customary) for the purpose intended'.

Herbs and spices have traditionally been traded as dried products for reasons of preservation. The industry goes back before the time of Christ (fragmentary written records exist from 2600 BC) when drying was one of the main forms of food preservation. Drying was then by means of the sun and this method is still widely used. With the advent of modern transport methods and methods of preservation, frozen herbs and fresh herbs and spices have made an appearance as items of trade, but the industry remains dominated by the trade in dried products. The major quality specifications are based mainly on dried herbs and spices.

2.2 Major international quality specifications

Herbs and particularly spices have always been highly-priced commodities and vulnerable to adulteration. In consequence simple standards evolved early. As an example, in 1180 in the United Kingdom in the reign of Henry II, a 'peppers' guild was established in London to set and enforce standards for spices. In 1429 it was incorporated into the Grocers Company which is still in existence. This guild was granted a charter by Henry VI to manage the trade in spices. This organisation was given exclusive power to garble (e.g. cleanse and separate) spices. The term is still in use today, for example in classifying types of pepper such as Tellicherry Garbelled Extra Bold Black Pepper (TGEB). Today the two major international standards are those set by the United States and those set by the European Union (EU). Standards relying on the same general parameters also exist in those countries responsible for growing herbs and spices, for example the Indian Spices Board and the Pepper Marketing Board. These standards are influenced by those set by the major importing countries.

There are various types of test which make up the range of international standards:

- *Cleanliness*. This is a measure of the amount of foreign and extraneous matter, for example insect contamination, excreta or foreign bodies. Measurement is by physical determination (using microscopic analysis ($\times$ 30)) of contamination within aliquots (samples) of the product.
- *Ash level*. This is a measure of the level of impurities in a product, obtained by burning off the organic matter and measuring the residue of ash. This measurement is carried out by incinerating the herb or spice at 550ºC to constant weight. Characteristic maximum figures exist for most herbs and spices.
- *Acid insoluble ash (AIA) (or sand content)*: This is a classic determination of the cleanliness of the herb or spice. The measure is usually made in conjunction with the ash content by boiling the ash in 2N HCl and incinerating the residue (again at 550ºC) to a constant weight. Again maximum figures exist for most herbs and spices. Prosecutions have in the past been based on high acid insoluble ash (AIA) levels within Europe, which are seen as indicating an unacceptably dirty product.
- *Volatile oil (V/O) determination*. This measure helps to identify whether the herb or spice has been adulterated, perhaps by addition of foreign materials, low quality or spent amounts of the herb or spice in question. The herb or spice is boiled under reflux conditions with water where the oil separates on top of the water and can be read off in a volume proportional to the mass of the product under test. Minimum percentage levels of oil exist for most major herbs and spices.
- *Moisture content*. This measure of the amount of moisture is important since moisture content determines weight, and weight is used in pricing. With highly priced commodities traded on weight, a 1% moisture increase in the product as shipped can result in increased weight and increased profits for the original exporter. Maximum moisture contents are set for all herbs and spices, based on the maximum allowable amount of moisture for the product to remain stable. Moisture content is generally determined within the herb and spice industry using the Dean & Stark methodology. This involves re-fluxing a known weight of the herb or spice in petroleum spirit and measuring the water that condenses at the bottom of the reflux chamber from the known weight of herb or spice. Generally the level is 12% max.
- *Water availability*. In recent years moisture content has been related to the A_w or the water availability of the herb or spice. The level of 0.6 A_w is generally accepted as a figure at and below which mould or microbial growth cannot occur. However, this

figure is increased in several herbs and spices without problem due to the preservative effect of the oils contained within the spices. Examples are cinnamon, oregano and cloves where the oils have very strong anti-microbial effects.

- *Microbiological measures*. There is a range of techniques available for counting the numbers of a pathogen in a sample.
- *Pesticide levels*. Pesticide levels are not seen as a major problem given the (low) average daily intakes of these products by consumers. As a result, in the EU limited legislation exists for herbs whilst, for spices, the EU has determined there is no risk and no legislation is planned. Legislation is in a state of flux in the USA and limits may be introduced. In the interim, Codex limits for the nearest equivalent commodity may be a useful guide. Pesticide levels are assessed by either gas chromatography (GC) or high performance liquid chromatography (HPLC), depending on the pesticide in question.
- *Mycotoxin levels*. Mycotoxins, specifically aflatoxin and ochratoxin A, have been of concern within the last few years in the industry. Legislation governing the aflatoxin content of capsicum species, piper species, nutmeg, ginger and turmeric will be enacted in 2001 within the European Union at 10ppb total, 5ppb B_1. With the USA the limit is currently 20ppb. HPLC is likely to be the reference methodology employed for these determinations.
- *Bulk density/bulk index*. This is an important measure, particularly in filling retail containers of herbs and spices. The herb or spices must be sifted or ground to give a certain density so that retail units appear satisfactorily full and comply with the declared weight. Densities may be measured packed down, e.g. after tapping the product so that it assumes a minimum density, or untapped: as it falls into the container without compression. This measure is usually defined as grams/litre or mls/100g.
- *Mesh/particle size*. Many spices and herbs are ground to give easier dispersion in the final food product. This process also aids the dispersion of flavour. Particle size is generally specified and is carried out using standardised sieves. Aperture sizes give a particle size, the products being ground to pass a certain sieve, and coarse matter recycled through the mill until it finally passes through the sieve. Sieves are characterised in micron sizes and typical requirements will be a 95% pass on a specified size of sieve. The older method of measuring sieve (hole) sizes was that of mesh which related to the number of holes per inch. However, confusing differences exist between American and British mesh sizes. The mesh size (number of holes per inch) depends on the diameter of the wire making up the sieves and this differs between nations. Thus a 25 mesh US sieve is equivalent to a 30 mesh BS (UK) sieve and both are equivalent to a 500 micron aperture size. Tables are available giving the relationships between national sieve sizes and micron sizes.

There are a number of internationally-approved standards for testing procedures, established by the International Standards Organisation (ISO). These include the following ISO standards:

Moisture	ISO 939
Total Ash	ISO 928
Acid Insoluble Ash	ISO 930
Volatile Oil	ISO 6571

2.3 The American Spice Trade Association (ASTA)

The American Spice Trade Association (ASTA) was established at the beginning of the twentieth century. Given its long involvement in regulating the quality of herbs and spices entering the USA, ASTA standards are recognised and endorsed by the United States Food & Drug Administration (USDA). Cleanliness specifications exist for all major herbs and spices, in terms of permitted amounts of extraneous matter or filth, mould (visible), insects, excreta and insect damaged material. The amount of contamination is measured by microscopic analysis ($\times$ 30) of aliquots of the material. These specifications are shown in Table 2.1. For the purposes of these specifications, extraneous matter is defined as everything foreign to the product itself, including, but not restricted to: stones, dirt, wire, string, stems, sticks, non-toxic foreign seeds, (in some cases) other plant material such as foreign leaves, excreta, manure and animal contamination. The level of contaminants permitted under these specifications must fall below those shown in Table 2.1, except for the column 'Whole insects, dead' which must not exceed the limit shown. These specifications provide a general standard of cleanliness. Herbs and spices not meeting this standard must be re-cleaned/re-conditioned before distribution and sale within the United States is allowed.

The ASTA also sets a range of other standards. These are broadly comparable to those set by the European Spice Association (ESA), which are discussed in the next section. Microbiological standards in particular now play an increasingly important role in determining the quality of herbs and spices. They are becoming a crucial quality parameter due to the increasingly varied uses of herbs and spices in the developed world. Increased travel has led to a society demanding multicultural foods. This coupled with ready meals, cook–chill products, etc., has meant that herbs and spices are not 'always cooked' as was assumed in the past. But the third world origin of many herbs and spices plus the concentration due to drying means these products can pose a potential microbiological risk. Total counts in excess of 10^6 are common and food pathogens such as *Salmonella* are estimated to be present in approximately 10% of consignments imported. There are currently three major methods of control.

- Principally within the United States, microbiological control is exercised by fumigation with ethylene oxide, a bactericidal gas. Sometimes multi-fumigations are used to achieve a satisfactory microbiological reduction.
- Irradiation is permitted for microbiological control of herbs and spices in many countries of the world. However, the use of the process must be declared on the packaging presented to the consumer and consumer concern about its use in foods have prevented the use of this undeniably efficient process in many areas where its use is permitted by law.
- In recent years concern about residues left by ethylene oxide has led to bans on its use (within the EU for example). This has led to the use of heat treatment for decontamination, generally using high pressure steam in highly specialised equipment.

2.4 The European Spice Association (ESA)

Standards in Europe are typified by the standards set by the ESA which draw both on national standards such as those issued by AFNOR (the French standards authority) and BSI (British Standards Institute), and international standards issued by the ISO (International Standards Organisation). The minimum general ESA quality standards for all herbs and spices are summarised in Table 2.2, whilst quality standards for specific

Table 2.1 American Spice Trade Association Cleanliness Specifications (effective 28 April, 1999; data courtesy of the ASTA) (SF = see footnote)

Name of spice, seed or herb	▲ Whole insects, dead by count	Excreta, mammalian by mg./lb.	Excreta, other by mg./lb.	Mould % by wgt.	Insect defiled/ infested % by wgt.	Extraneous/ foreign matter % by wgt.
Allspice	2	5	5.0	2.00	1.00	0.50
Anise	4	3	5.0	1.00	1.00	1.00
Sweet basil	2	1	2.0	1.00	1.00	0.50□
Caraway	4	3	10.0	1.00	1.00	0.50
Cardamom	4	3	1.0	1.00	1.00	0.50
Cassia	2	1	1.0	5.00	2.50	0.50
Cinnamon	2	1	2.0	1.00	1.00	0.50
Celery seed	4	3	3.0	1.00	1.00	0.50
Chillies	4	1	8.0	3.00	2.50	0.50
Cloves*	4	5	8.0	1.00	1.00	1.00*
Coriander	4	3	10.0	1.00	1.00	0.50
Cumin seed	4	3	5.0	1.00	1.00	0.50
Dill seed	4	3	2.0	1.00	1.00	0.50
Fennel seed	SF(2)	SF(2)	SF(2)	1.00	1.00	0.50
Ginger	4	3	3.0	SF(3)	SF(3)	1.00
Laurel leaves†	2	1	10.0	2.00	2.50	0.50
Mace	4	3	1.0	2.00	1.00	0.50
Marjoram	3	1	10.0	1.00	1.00	1.00□
Nutmeg (broken)	4	5	1.0	SF(4)	SF(4)	0.50
Nutmeg (whole)	4	0	0.0	SF(5)	SF(5)	0.00
Oregano‡	3	1	10.0	1.00	1.00	1.00□
Black pepper	2	1	5.0	SF(6)	SF(6)	1.00
White pepper¶	2	1	1.0	SF(7)	SF(7)	0.50
Poppy seed	2	3	3.0	1.00	1.00	0.50
Rosemary leaves	2	1	4.0	1.00	1.00	0.50□
Sage†	2	1	4.0	1.00	1.00	0.50
Savory	2	1	10.0	1.00	1.00	0.50□
Sesame seed	4	5	10.0	1.00	1.00	0.50
Sesame seed, hulled	4	5	1.0	1.00	1.00	0.50
Tarragon	2	1	1.0	1.00	1.00	0.50□
Thyme	4	1	5.0	1.00	1.00	0.50□
Turmeric	3	5	5.0	3.00	2.50	0.50

Ground processed spice (cannot exceed limit shown)

Spices	Whole equivalent insects	Insect fragments	Mites	Other insects	Rats/ mouse hairs	Animal hairs
Ground Paprika		Averag of more than 75 fragments/ 25g			Average of more than 11 rodent hairs/25 g	

Table 2.1 Continued

* Clove Stems: Less than 5% allowance by weight for unattached clove stems over and above the tolerance for other extraneous matter is permitted.
† Laurel leaves/sage: 'Stems' will be reported separately for economic purposes and will not represent a pass/fail criteria.
‡ Oregano: Analysis for presence of Sumac shall not be mandatory if samples are marked 'Product of Mexico.'
¶ White pepper: 'Percent Black Pepper' will be reported separately for economic purposes and will not represent a pass/fail criteria.
(2) Fennel seed: In the case of Fennel Seed, if 20% or more of the sub-samples contain any rodent, other excreta or whole insects, or an average of 3 mg/lb or more of mammalian excreta, the lot must be reconditioned.
(3) Ginger: More than 3% mouldy pieces and/or insect infested pieces by weight.
(4) Broken nutmeg: More than 5% mould/insect defiled combined by weight.
(5) Whole nutmeg: More than 10% insect infested and/or mouldy pieces, with a maximum of 5% insect defiled pieces by count.
(6) Black pepper: 1% mouldy and/or infested pieces by weight.
(7) White pepper: 1% mouldy and/or infested pieces by weight.
▲ *Whole insects, dead*: Cannot exceed the limits shown.
□ Extraneous matter: Includes other plant material, e.g. foreign leaves

herbs and spices are shown in Table 2.3. The ESA general standards are more relaxed in their quantitative figures as they represent *minimum* standards allowable for trade. They do not preclude buyer and seller setting further standards fit for the final purpose for which the herb and spice is to be used.

2.5 Other tests

There are a number of other tests used in the industry, some of which are for specific herbs or spices. Some of the best-known and widely used are:

- *Piperine levels*. The test is specifically for peppers of the piper species. This involves extraction measurement of the characterising heat portion of the pepper the piperine content. After refluxing in alcohol to extract the piperine, absorbency is compared to a standard in a spectrophotometer at 342–345 nm.
- *(ASTA) Colour values*. This is a measurement of the extractable colour of products of the capsicum species and its principal use is a quality indicator for paprika. Extraction is in acetone over a 16 hour ambient extraction period and again the methodology is spectrophotometric against a standard at 460 nm. The methodology was developed by the American Spice Trade Association and it is still often known as the ASTA colour value.
- *Capsaicin content*. Capsaicin is the pungent principle that gives heat to the capsicum species. Extraction of capsaicin is by re-fluxing with alcohol. The determination is by HPLC using acetonitrile/water as the carrier. It can be related to the Scoville test (see below).
- *Scoville heat units*. The Scoville heat unit is a measure of the heat levels (capsaicin content) of the capsicum species. It involves extraction of the capsaicin in alcohol and tasting of successively stronger dilutions in sugar syrup until the chillie heat is detected. It gives a compatible result to capsaicin content but obviates a need for sophisticated laboratory equipment. A trained tasting panel is required. (Scoville units divided by 150,000 = percent capsaicin.)
- *Curcumin content*. This is a test specific to the measurement of the extractive colour of turmeric. This is carried out by reflux extraction in acetone followed by measurement using a spectrophotometer at 415–425 nm.

Table 2.2 European Spice Association (ESA) specifications of quality minima for herbs and spices (courtesy of the ESA)

Subject	
Extraneous matter	Herbs 2%, Spices 1%
Sampling	(For routine sampling) Square root of units/lots to a maximum of 10 samples. (For arbitration purposes) Square root of all containers e.g. 1 lot of pepper may = 400 bags, therefore square root = 20 samples.
Foreign matter	Maximum 2%
Ash	See Table 2.3
Acid insoluble ash (AIA)	See Table 2.3
Moisture content (H_20)	See Table 2.3
Packaging	Should be agreed between buyer and seller. If made of jute and sisal, they should conform to the standards set by CAOBISCO Ref C502-51-sj of 20-02-95.
Heavy metals	Shall comply with national/EU legislation.
Pesticides	Shall be utilised in accordance with manufacturers' recommendations and good agricultural practice and comply with existing national and/or EU legislation.
Treatments	Use of any EC approved fumigants in accordance with manufacturers' instructions, to be indicated on accompanying documents. (Irradiation should not be used unless agreed between buyer and seller.)
Microbiology	Salmonella absent in (at least) 25g. Yeast and moulds 10^5/g target, 10^6/g absolute maximum *E. Coli.* 10^2/g target, 10^3/g absolute maximum Other requirements to be agreed between buyer and seller.
Off odours	Shall be free from off odour or taste.
Infestation	Should be free in practical terms from live and/or dead insects, insect fragments and rodent contamination visible to the naked eye (corrected if necessary for abnormal vision).
Mycotoxins	*Aflatoxins* Should be grown, harvested, handled and stored in such a manner as to prevent the occurrence of aflatoxins or minimise the risk of occurrence. For capsicum species, piper species, nutmegs, turmeric and ginger, the maximum permitted EC levels from 1 July 2001 are total aflatoxin 10ppb maximum, and B1 5ppb maximum. *Ochratoxin A* Should be grown, harvested, handled and stored in such a manner as to prevent the occurrence of ochratoxin A or minimise the risk of occurrence.
Volatile oil (V/O)	See Table 2.3.
Adulteration	Shall be free from.
Bulk density	To be agreed between buyer and seller.
Water activity	To be agreed between buyer and seller
Species	To be agreed between buyer and seller.
Documents	Should provide: details of any treatments the product has undergone; name of product; weight; country of origin; lot identification/batch number; year of harvest.

Table 2.3 Quality standards for specific herbs and spices (courtesy of the European Spice Association)

Product (whole form)	Ash % w/w max	AIA % w/w max	H_2O % w/w max	V/O % w/w min
Aniseed	9 (ISO)	2.5 (AFNOR)	12 (ISO)	1 (ISO)
Basil (BSI)	16	3.5	12	0.5 (ESA)
Bay (ISO)	7	2	8	1
Cardamom (ESA)	9	2.5	12	4
Cassia (ESA)	7	2	14	1.0
Celery seed (ISO)	12	3	11	1.5
Chervil (ESA)	17	2	8	–
Chilli (ISO)	10	1.6	11	–
Chives (ESA)	13	2	8	–
Cinnamon (ESA)	7	2	14	0.4
Cloves	7 (ISO)	0.5 (ISO)	12 (ISO)	14 (AFNOR)
Coriander	7 (ISO)	1.5 (ISO)	12 (ISO)	0.3 (ESA)
Cumin (ESA)	14	3	13	1.5
Dill tops (ESA)	15	2	8	–
Dill seed (ESA)	10	2.5	12	1
Dutch caraway (ISO)	8	1.5	13	2.5
Fennel seed (ISO)	9	2	12	1.5
Fenugreek (ISO)	7	2	12	–
Garlic powder	6 (ESA)	0.5 (ISO)	7 (ESA)	– (ISO)
Ginger	8 (ISO)	2 (ESA)	12 (ISO)	1.5 (ISO)
Mace (ISO)	4	0.5	10	5
Marjoram (ISO)	10	2	12	1
Mint (ISO)	12	2.5	13	0.5
Mustard (BSI)	6.5	1	10	–
Nutmeg	3 (ISO)	0.5 (ISO)	12 (ESA)	6.5 (ESA)
Onion powder (ISO)	5	0.5	6	–
Oregano (BSI)	10	2.5	12	1.5 (ESA)
Paprika powder (ESA)	10	2	11	–
Parsley (not English) (ESA)	14	1.5	7.5	–
Pepper black	7 (ISO)	1.5 (ESA)	12 (ESA)	2 (ISO)
Pepper white	3.5 (ISO)	0.3 (ISO)	12 (ESA)	1.5 (ESA)
Pimento				
Jamaica	5 (ESA)	0.4 (ISO)	12 (ISO)	3.5 (ISO)
Other origins	5 (ESA)	1 (ESA)	12 (ISO)	2 (ESA)
Rosemary	8 (ESA)	1 (ESA)	10 (ISO)	1 (ISO)
Saffron whole (ISO)	8	1	12	–
Saffron ground (ISO)	8	1.5	10	–
Sage (ISO)	12	2	12	1.5
Savory (ESA)	12	2	12	0.5
Tarragon (ESA)	12	1.5	8	0.5
Thyme	14 (ISO)	4 (ESA)	12 (ISO)	1 (ISO)
Turmeric				
Whole (BSI)	8	2	12	2.5
Ground	9 (ISO)	2.5 (ESA)	10 (ISO)	1.5 (ESA)

AFNOR Association Française de Normalisation
BSI British Standards Institute
ESA European Spice Association
ISO International Standards Institute

2.6 Quality assurance systems

Quality assurance (QA) systems for raw materials should be planned and documented using Hazard Analysis and Critical Control Point (HACCP) principles. Any quality assurance system should start with a comprehensive raw material specification agreed with the supplier, where this is possible. This specification needs to be supported by an audit of the supplier to verify that the supplier has the expertise, technology and quality assurance system to meet the agreed specification. In many cases, however, given the lack of infrastructure and resources within many supplier countries, suppliers will be unable to comply with all aspects of a specification. In these circumstances, the company purchasing the material must rely on effective QA systems of its own. As well as appropriate procedures, effective QA systems rely for their success, in most cases, on experienced personnel.

The material as imported should firstly be inspected on delivery. The first inspection should be an overall inspection of the product as the doors of the container are opened or the load is made accessible. This necessarily basic first inspection is made to look for large-scale infestation, mould growth, unacceptable packaging, rodent infestation or an unsuitable container, e.g. one previously used for chemicals, which have contaminated the spice or herb.

The quality control system should then cover sampling and examination of the raw material. Sampling of the material for these tests should be on a square root basis throughout the load to a maximum of 10 samples. This should initially be physical and examine the amount of dust (with the aid of sieves as appropriate), the amount of stalks, stem, extraneous matter, etc. and most importantly the colour, flavour and general appearance of the product. This should be then backed up with tests relevant to the product for volatile oil, moisture, ash, acid insoluble ash, etc. Any tests specific to the material should also be carried out at this time. Microbiological testing at this stage should be carried out for the presence of *Salmonella* and *E. Coli* and the product positively released on the attainment of these parameters (generally *Salmonella* ND/25g, *E. Coli* <100 cfu/g). During this period, the product should be quarantined and no further processing permitted. Unacceptable material should be rejected or in certain cases may be reconditioned, e.g. re-cleaned, dried, etc., to bring it within the required parameters. This may be carried out in-house or at a specialist processor. Microbiologically unsatisfactory material may be gas treated or heat treated at this stage. Positive microbiological release should be employed on a pallet basis subsequent to heat treatment. Also incorporated within the QA system should be procedures for removing metal of all types. Characteristically this should consist of the use of metal detection/magnets at appropriate stages during processing and with obligatory use immediately prior to packing.

2.7 References

Clean Spices – a handbook for ASTA members.
Official Analytical Methods of the American Spice Trade Association.
Official Microbiological Methods of the American Spice Trade Association.
BS4547 Specification for Herbs and Spices.
BS7087 Methodology for Analysis of Herbs and Spices
ISO series: Specifications for Herbs and Spices.
European Spice Association: Quality Minima for Herbs and Spices.

3

Quality indices for spice essential oils

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3.1 Introduction

Essential oil fractions and oleoresins derived from spices are used widely in the food industry to provide flavour. Some of the main essential oils and their origins are shown in Table 3.1.

Determining the quality and purity of essential oils faces similar difficulties to establishing the quality of raw spices, given the accepted variations in and mixing of varieties within a particular spice. There are, however, a number of properties that can be used to set quality standards. These include physical characteristics such as:

- specific gravity
- molecular refractive index
- optical rotation
- solubility.

It is also possible to use chemical properties to benchmark quality. These include determination of acids, esters, alcohols, aldehydes and ketones, phenols and iodine number. Some specific flavour tests for halogens can also be used to set standards (Guenther 1972). An overview of these quality indices is provided in the appendix at the end of this chapter.

3.2 The problem of adulteration

Adulteration has been a serious problem for many years in the area of essential oils. Undoubtedly the economic incentive to blend synthetic flavourants with natural oil is too high to resist. Some essential oils naturally contain a single compound at high concentration, and often the synthetic counterpart of this major component is available at a low cost. Addition of this single compound to natural essential oils without declaration on the label amounts to adulteration.

Table 3.1 Major essential oils – their production and adulterants

Essential oil	Origin	Major countries	Adulterants employed
Bergamot oil	*Citrus auranticum* (Rutaceae)	Italy, Ivory Coast, Brazil Argentina, Spain, Russia	synthetic linalool and linalyl acetate; orange and lime terpenes
Cassia oil	*Cinnamonum cassia* (Lauraceae)	China, Indonesia, Vietnam, Taiwan	cinnamaldehyde
Cinnamon oil	*Cinnamonum zeylanicum* (Lauraceae)	Sri Lanka, India	leaf oil to bark oil and cinnamaldehyde
Clove leaf oil	*Eugenia caryophyllata* (Myritaceae)	Madagascar, Indonesia, Tanzania, Brazil, Sri Lanka	clove stem oil
Clove bud oil	*Eugenia caryophyllata* (Myritaceae)	Indonesia, Madagascar	clove stem oil, leaf oil, eugenol, and stem oil terpenes
Coriander oil	*Coriandrum sativum* (Umbelliferae)	Russia	synthetic linalool
Cornmint oil	*Mentha arvensis* (Labiatae)	China, Brazil, India, Paraguay, Taiwan, Thailand, North Korea, Japan	not a commercially attractive proposition
Dill oil	*Anethum graveolens* (Umbelliferae)	US, Hungary, Bulgaria, Russia Egypt	distilled orange terpenes
Eucalyptus oil	*Eucalyptus globus* (Myrtaceae)	Portugal, S. Africa, Spain, China, India, Austria, Paraguay	–
Garlic oil	*Allium sativum* (Liliaceae)	Mexico, Italy, Egypt	nature identical raw materials
Ginger oil	*Zingiber officinale* (Zingiberaceae)	China, India	not often adulterated
Grapefruit	*Citrus paradisi* (Rutaceae)	Brazil, US, Israel, Argentina, New Zealand	orange terpenes
Lemon oil	*Citrus limon* (Rutaceae)	Argentina, US, Italy, Brazil, Greece, Spain, Australia, Peru	distilled oil and terpenes

Table 3.1 Continued

Essential oil	Origin	Major countries	Adulterants employed
Lemongrass	*Citrus flexuosus* and *C. citratus* (Gramineae)	India, China, Guatemala, Brazil, Russia, Sri Lanka, Haiti, Russia	synthetic citral
Lime oil	*Citrus aurantifolia* (Rutaceae)	Mexico, Peru, Haiti, Brazil Ivory Coast, Cuba, Ghana, Jamaica, China	synthetic terpineol terpinolene, and other components of lime terpenes
Litsea cubeba oil	*Litsea cubeba* (Lauraceae)	China	synthetic citral
Nutmeg	*Myristica fragrens* (Myristicaceae)	Indonesia, Sri Lanka,	terpenes and nature identical raw materials
Sweet orange oil	*Citrus sinensis* (Rutaceae)	Brazil, US, Israel, Italy, Australia	adulteration infrequent but higher priced oils diluted with cheaper substitutes
Peppermint oil	*Mentha piperita* (Labiatae)	US, Russia, Yugoslavia, Hungary, France	cornmint oil, terpenes
Rose oil	*Rosa damascena* (Rosaceae)	Turkey, Russia, Bulgaria, Morocco	nature identical components such as citronellol and geraniol
Rosemary oil	*Rosamarinus officinalis* (Labiatae)	Spain, Morocco, Tunisia, Russia, Yugoslavia, Turkey	camphor and eucalyptus fraction
Spearmint oil	*Mentha spicata* (Labiatae)	US, China, Italy, Brazil, Japan, France	laevo carvone
Star anise oil	*Illicium verum* (Magnoliaceae)	China, Vietnam, North Korea, Russia	anethole
Tangerine oil	*Citrus reticulata* (Rutaceae)	Brazil, US, Russia, Spain, South Africa	synthetic methyl-n-methyl anthranilate

Source: Singhal *et al.* (1997).

3.2.1 Addition of synthetic flavourants

Synthetic flavour compounds contain impurities characteristic of the synthetic route used to prepare them. These impurities can be quantified by selected ion monitoring (SIM), gas chromatography/mass spectrometry (GC/MS) in essential oils, and their absence is an

indication of the essential oil being natural (Frey 1988). For instance, the presence of impurities such as phenyl pentadienal, benzyl alcohol and eugenol in synthetic cinnamaldehyde forms the basis of its detection in natural cassia oil. These impurities could be quantified by GC/MS, and levels as low as 0.55 parts of synthetic cinnamaldehyde in natural cassia oil can be detected (Zhu *et al*. 1996). The common adulterants for spice essential oils are listed in Table 3.1. A mass spectrometer usually scans over a range of trace compounds in order to obtain data on every component in a mixture. The decrease in the number of masses detected using SIM results in a 10-fold to 100-fold increase in detection sensitivity for a single compound.

3.2.2 Addition of edible and mineral oils

Both edible and mineral oils are often used for adulteration (Nour-el-Din *et al*. 1977). The mixing of expensive oils with cheaper oils can often be detected by running a GC profile of the oil. One approach is to search for components in the expensive oil which are not commercially available, and are unique to the oil. An example is β-selinene in the oil of celery. A good quality oil should contain 7.0–7.5% β-selinene (Straus and Wolstromer 1974). Oils containing less than 7.0% β-selinene should be suspected of being adulterated.

3.2.3 Dilution with ethyl alcohol

Ethyl alcohol represents the main alcohol usually used in moderate quantities to dilute essential oils (Mostafa *et al*. 1990a). Dilution of essential oils with ethanol was checked using refractometric methods which were found to be unreliable (Kaminski and Dytkowska 1960). These and many other adulterations can be identified by infra-red (IR), gas chromatography (GC), and thin-layer chromatography (TLC) (Di Giacomo and Calvarano 1973). TLC has been found to be a simple method of checking adulteration in essential oils of caraway, coriander, parsley and anethum (Hoerhammer *et al*. 1964). Detection of nature-identical flavouring substances in high-value genuine onion oil is based on the GC/MS, or IR spectroscopy of the onion furanone, 2-n-hexyl-5-methyl-3(2H) furanone (Losing 1999). This technique is both simple and rapid.

3.2.4 Iodine number for detection of adulteration

Iodine number has been suggested as a means of detecting adulteration in essential oils (Kartha and Mishra 1963), but the iodine number has not attained significance in assessing the quality of essential oils probably due to unpredictable behaviour of these oils in the presence of solutions, commonly employed for iodination. The observation that the iodine monobromide-mercuric acetate reagent brings about quantitative fission of the cyclopropane and cyclobutane rings in essential oils prompted Kumar and Madaan (1979) to make use of such iodine absorption values for this purpose. Table 3.2 gives the recommended iodine values for pure specimens of various essential oils and isolates. The method could detect adulteration successfully in samples considered to be unadulterated on the basis of conventional analytical procedures.

3.2.5 Physical methods for detection of adulteration

Physical methods such as specific gravity at 25ºC, refractive index at 25ºC, specific optical rotation, freezing point and chemical parameters such as ester number have been

Table 3.2 Recommended iodine values for pure specimens of various oils and isolates

Essential oli/isolate	Recommended iodine value
Oil of ajowan, lab. distilled[a]	232–265
Oil of fennel, lab. distilled[a]	160–185
Oil of dill, lab. distilled[a]	265–307
Oil of clove, lab. distilled[a]	232–243
Oil of cinnamon leaf, lab. distilled	46–52
Oil of black pepper, lab. distilled	300–324
Oil of cumin seed, lab. distilled	193–195
Oil of lavidin (abrialis)[b]	167
Oil of parsley seeds, lab. distilled[a]	248
Oil of spike lavender[b]	135
Oil of black jeera, lab. distilled[a]	230
Oil of *Curcuma amada*, lab. distilled[a]	266
Oil of *Piper longum* lab. distilled[a]	265
Oil of dry ginger, lab. distilled[a]	185
Oil of *Pimpenella anisum*, lab. distilled[a]	296
Vanillin, pure, BDH[b]	58
Menthol, pure, lab. distilled	0
Eugenol, pure, lab. distilled	275
Oil of peppermint, dementholized (Japan)[b]	68

[a] Samples collected from different places
[b] Samples procured from different companies.
Source: Kumar and Madaan (1979) (reproduced with permission).

useful in detecting adulteration. Table 3.3 gives the critical region (borderline) for detection of a sample of essential oils by these different methods. Such physical properties including ester number should be considered as presumptive tests and should be confirmed by other, more specific analysis. A freezing point lower than 10.5ºC is indicative of turpentine in peppermint oil (Lu 1994). Colorimetric analysis of glycerol can indicate adulteration with edible oils. TLC of the hydrocarbon fraction, GLC and IR are effective in detecting adulterant ethanol, edible oils and liquid paraffins (Mostafa *et al*. 1990b). The presence of cottonseed oil in different essential oils gave absorption bands characteristic of esters and unsaturated esters (at 1705–1720 cm^{-1}), acetates (at 1245 cm^{-1}) and the carbonyl group (at 1250–1170 cm^{-1}), while the presence of paraffin oil gave a broadened absorption band at 3000 cm^{-1} which characterizes the saturated and unsaturated hydrocarbons. Mineral oil in peppermint oil can be detected as turbidity, when peppermint oil is added to 60–80% ethanolic solution (Lu 1994).

3.2.6 Authentication of botanical and geographical origin of essential oils

Aroma constituents of essential oils such as linalool and linalyl acetate can be traced to various botanical sources such as coriander, lavender, etc. Authentication methods that could trace the botanical and even the geographical origin of such constituents are a challenge to food analytical chemists. Information of such aspects is just beginning to emerge in scientific literature. For instance, analysis of major volatile constituents has demonstrated the ratio of carvaerol/thymol to differentiate essential oils from four oregano species (Pino *et al*. 1993). Rosemary essential oil of different geographical origins could be differentiated on the basis of GC/MS determination of natural constituents. While Spanish oils are rich in α-pinene (19.4–24.7%), 1,8-cineole (19.0–21.8%) and camphor (16.3–18.9%), the French oils contain α-pinene (19.9–35.1%), 1,8-

Table 3.3 Critical region (border line) for detection of adulterated oils by different adulterants[a]

Properties	Marjoram	Petit grain	Fennel
Adulterants added (%)		bigrade	
Specific gravity at 25ºC	0.94139	0.90820	0.97336
Ethanol	>10	>0.5	>15
Paraffin oil	>10	>0.5	>1
Cottonseed oil	>20	>5	>15
Refractive index at 25ºC	1.44520	1.4919	1.5198
Ethanol	>20	>0.5	>10
Paraffin oil	>0.5	–	>10
Cottonseed oil	>0.5	–	>10
Specific optical rotation:	13.45	3.08	6.39
Ethanol	>5	–	>10
Paraffin oil	>5	>40	>10
Cottonseed oil	>5	40 only	>105
Ester number	45.16	193.4	17.22
Ethanol	>15	>5	>0.5
Paraffin oil	>20	>10	>0.5
Cottonseed oil	>0.5	–	>2

[a] Significant at 5% level.
– Not detected.

cineole (5.3–24.8%) and bornyl acetate (1.2–14.3%). Moroccan oils are typically rich in 1,8-cineole (43.5–57.7%) (Chalchat *et al*. 1993). However, chemical analysis is not always helpful in determining the geographical origin of essential oils as has been shown with sage essential oils (Lawrence 1994, 1998).

Authentication of saffron oil on the basis of $\delta\ ^{13}C/^{12}C$ of safranol, as measured by isotopic mass spectroscopy has been reported (Bigois *et al*. 1994). Site-specific natural isotope fractionation studied by NMR (SNIF-NMR) combined with molecular isotope ratio determination by mass spectrometry (IRMS) can characterize linalool and linalyl acetate from chemical synthesis or extracted from essential oils of well defined botanical and geographical origins. Chirality can be used as a criterion for differentiation between components of natural and nature-identical types (Werkhoff *et al*. 1991) as well as mixing of components such as linalool from different sources. It can be achieved by using enantioselective capillary GC coupled with stable isotope ratio analysis (Hener *et al*. 1992).

The overall ^{13}C or ^{2}H contents, as measured by IRMS do not constitute an efficient criterion for such identifications. The GC-IRMS method has serious limitations, since the $\delta\ ^{13}C$ values of most C_3 plants (including spices) partially overlap with those of synthetic substances of fossil origin. This can be overcome by using internal isotopic standards, which can then be used to obtain an 'isotopic fingerprint', typical of a plant. A genuine natural essential oil would then have $\delta\ ^{13}C$ values that are identical with the 'isotopic fingerprint'. This approach has been successful with coriander essential oils (Frank *et al*.

1995). The presence of ^{14}C in cinnamaldehyde, as the main constituent in cinnamon essential oil, and its absence in the synthetic counterpart formed the basis of their distinction. Unfortunately, this technique was overcome by addition of ^{14}C enriched cinnamaldehyde. A strategy wherein the cinnamaldehyde is transformed into benzaldehyde via a controlled retroaldolization reaction followed by measuring the deuterium content in the ^{2}H-NMR at a very high magnetic field can distinguish as little as 10–15% synthetic cinnamaldehyde in cinnamon oil. This technique is superior to the IRMS technique, which determines the total deuterium content (Remaud *et al*. 1997). Further, model studies with linalool and linalyl acetate have shown $\delta\ ^{13}C$ values to be influenced by the method and conditions used in their extraction (Weinrich and Nitz 1992). Non-random distribution of deuterium exhibits large variations as a function of the origin of the sample. Discriminant analysis performed over the natural and synthetic families show all synthetic samples to belong to the same group. Natural linalool is characterized by a strong depletion in the heavy isotope in site 1 and by a relative enrichment at site 6. Semi-synthetic linalool obtained from pinene can also be distinguished from natural linalool by virtue of its deuterium at site 3 of the sample. The discrimination between linalools of various botanical origins is, however, reported to be only 82% effective (Hanneguelle *et al*. 1992). Very recently, an on-line gas chromatography pyrolysis isotope ratio mass spectrometry has been developed that can easily bring out clear cut origin dependent differences in $^{2}H/^{1}H$ ratios in case of E-2-hexenal and E-2-hexenol demonstrating the importance and potential of this technique in authenticity studies of flavour constituents in complex natural matrices (Hor *et al.*, 2001). Similarly, enantiometric purity of carvone from essential oils of caraway, dill and spearmint can be determined using appropriate enantioselective columns. While *S*(+)-carvone is detected in herb oils of caraway and dill, spearmint oils from various countries contain only *R*(-)-carvone (Ravid *et al*. 1992).

The differentiation between compounds that are grown naturally, produced by fermentation or synthesized chemically is projected to reflect in legal regulations in the coming years. Hence, intensive and comprehensive basic investigations on the analytical origin assessment of flavours will gain ground.

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Appendix: Physical properties of some spice essential oils and flavourants

Spice	Specific gravity (20°C)	Refractive index (20°C)	Optical rotation (°) (20°C)	Solubility characteristics	Other remarks
Asafoetida	0.906–0.973	1.493–1.518	−9°0′ to +9°18′		Sulphur content, 15.3–29%
Allspice (Pimenta) berry oil	1.024–1.055[a]	1.525–1.536	−0°32′ to −5°0′	Soluble in 1–2 vols and more of 70% alcohol, occasionally with opalescence to turbidity on dilution	Phenol content, 65–89%
Pimenta leaf oil	1.026–1.065	1.530–1.540	inactive to 5°30′	Soluble in1–2 vols of 70% alcohol	Phenol content, 65–96%
Bay oil	0.960–0.985;[a] in oils of lower quality as low as 0.951	1.506–1.520	laevorotatory up to −2°, seldom up to −3°	Freshly distilled oils are soluble usually in 1–2 vols of 70% alcohol; solubility decreases rapidly on storage	Phenol content 57–60%; in oils of poor quality, as low as 40%
Terpeneless bay oil	1.029–1.050′	1.527–1.536	−0°10′ to −1°20′	Soluble in 2–2.5 vols of 60% alcohol, sometimes even in 6–6.5 vols of 50% alcohol	Phenol content, 82–95.5%
Cardamom	0.923–0.941[a]	1.462–1.467	+24°0′ to +41°	Soluble in 2–5 vols of 70% alcohol	Acid number, up to 4; Ester number, 92–150
Cardamom, wild	0.909′	1.474	+16°30′	Soluble in 1–2.5 vols of 70% alcohol	Acid number, 1.1; Ester number, 12
Cinnamon bark oil	1.020–1.030′	1.568–1.535	−1°0′ to −2°10′	Soluble in 1–2.5 vols of 70% alcohol, occasionally opalescent to hazy	Aldehyde (calcd. as cinnameldehyde), 51.8–56% Phenol (Eugenol), 14–18%
Cinnamon leaf oil	1.037–1.055[a]	1.529–1.535	1°36′ to 0°40′	Soluble in 1.5 vols or more of 70% alcohol, sometimes with opalescence or paraffin separation	Adehyde, up to 4% Phenol, 77.3–90.5%

Cassia oil	1.055–1.070[a]	1.600–1.606	−1°0′ to +6°0′	Readily soluble in 1–2 vols of 80% alcohol, 2–3 vols of 70% alcohol	Aldehyde, 75–90%
Clove bud oil	1.043–1.068[a]	1.529–1.537	up to −1°35′	1–2 vols or more of 70% alcohol with slight turbidity; freshly distilled in 2.5–3.0 vols of 60% alcohol	Eugenol, 78–95%, seldom up to 98%
Clove stem oil	1.040–1.067[a]	1.531–1.538	up to −1°30′	1–2 vols or more of 70% alcohol and 2.5–3 vols of 60% alcohol	Eugenol, 83–95%, in exceptional cases higher
Clove leaf oil	1.032–1.067[a]	1.533–1.539	−0°50′ to −1°53′	0.9 vols or more of 70% alcohol	Eugenol, 78–93%
Ginger	0.877–0.886[a] oils with lower and higher specific gravity have been observed	1.489–1.494	−26°0′ to −50°0′ lower values observed for oil distilled from old roots stored for a long time	Only sparingly soluble in alcohol. Up to 7 vols of 95% alc reqd. for solution which is not always clear. In 90% alc, the oils are generally, but not always completely soluble	Acid number, up to 2; Ester number, up to 15; Ester number after acetylation, 24–50
Mustard	1.014–1.030	1.527–1.529	inactive	Soluble in 160 to 300 parts of water, 7–10 parts of 70% alcohol, 2.5–3.0 vols of 80% ethanol, in 0,5 vols of 90% ethanol, clearly miscible with ether, amyl alcohol, benzene and petroleum ether	Allyl isothiocynate, 94%; boiling range ar 760 nm, 148–154°C
Nutmeg	0.859–0.868	1.469–1.472	+40°48′ to +49°48′		Acid number, 1.0–1.3; Ester number, 6.8–7.3
Mace	0.860–0.892	1.472–1.479	+21°42′ to +41°30′		Acid number, 1.5–6.2; Ester number, 2.8–12.8
Oil of Wintergreen	1.180–1.193[a]	1.535–1.536	−0°25′ to −1°30′	Clearly soluble in 6–8 vols of 70% alcohol	Ester number, 354–365; Ester content, calcd. as methyl salicylate, 96–99%

Appendix (continued)

Spice	Specific gravity (20°C)	Refractive index (20°C)	Optical rotation (°) (20°C)	Solubility characteristics	Other remarks
Onion	1.047–1.098[a]	1.537–1.559	+1°3′ to +3°53′	Most oils not completely soluble in 10 vols of 95% alcohol. Occasionally soluble in 1–2 vols or more of 95% alcohol	Acid number, 12.0–19.8; Carbonyl number, 9.8–15.1; Iodine number, 59.9–66.2
Pepper oil	0.873–0.916	1.480–1.499	−10°0′ +3°	Not readily soluble in alcohol, usually soluble in 10–15 vols of alc; soluble in 3–10 vols of 95% alcohol	Acid number, up to 1.1 Ester number, 0.5 to 6.5 Ester number after acetylation, 12–22.4; Phellandrene test, usually strongly positive
Star anise	0.98–0.00	1.553–1.557	up to −2°; sometimes up to 0°36′	Soluble in 1.5–3.0 vols of 90% alcohol	Congealing point, +14–+18°
Ajowan oil	0.910–0.930[a]	1.498–1.504	up to 5°0′	Soluble in 1–2 vols and more of 80% alcohol	Phenols, 45.0–57.0%
Coriander	0.870–0.885[a]	1.463–1.471	+8°0′ to +13°0′	Soluble in 2–3 vols of 70% alcohol	Acid number, up to 5.0; Ester number, 3.0–22.7
Dill	0.895–0.915[a]	1.481–1.491	+70°0′ to +82°0′	Soluble in 4–9 vols of 80% alcohol	Carvone content, 40–60%
Anise oil	0.980–0.990	1.552–1.559	up to −1°50′	Soluble in 1.5–3.0 vols of 90% alcohol	
Fennel seed oil	0.965–0.977[a]	1.528–1.539	+11°0′ to +24°0′	Soluble in 5–8 vols of 80% alcohol and in 0.5 vols of 90% alcohol	Congealing point, not below 5°, and as high as 10° in good oils
Celery seed oil	0.872–0.891[a]	1.480–1.484	+65°53′ to +76°51′	Turbid in 90% alcohol	Saponification number, 25.1–47.6

Caraway seed oil	0.907–0.919[a]	1.484–1.488	+70º0′ to +81º0′	Seldom soluble in 70% alcohol, soluble in 2–10 vols of 80% alc., clearly soluble in equal vols of 90% alcohol	Carvone content, 50.0–60%
Parsley seed oil	1.043–1.110[a]	1.512–1.528	−4º0′ to −10º8′	4–8 vols and more of 80% alcohol	Acid number, up to 6; Ester number, 1 to 11, Ester number after acetylation, 4 to 20
Parsley herb oil	0.902–1.016[a]	1.509–1.526	+1º16′ to +4º30′	Soluble in 95% alcohol	Acid number, up to 1, Ester number, 5 to 14, Ester number after acetylation, 19–68
Lemongrass oil	0.899–0.911[a]	1.485–1.490	−1º10′ to −3º10′	2–2.5 vols of 70% alcohol; occasionally opalescent or slightly cloudy. A few lots not clearly soluble in 70% alcohol, up to 10 vols	Aldehyde content, 71.8–79.1%
Bitter almond oil	∼1.050[a]	1.542–1.546	inactive	Soluble in 1–2 vols and more of 70% alcohol	Boiling point 179ºC
Sassafras oil	1.070–1.080[a]	about 1.530	+2º0′ to +3º38′	Soluble in 95% alcohol, 1–2 vols of 90% alcohol	Acid number, up to 1.0, Ester number, 0.5–5.0 Congealing point, 4.5–6.9ºC

[a] at 15ºC.
Source: Singhal *et al.* (1997).

4

Organic spices

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4.1 Introduction

Global awareness of health and environmental issues is spreading fast in recent years, especially in the developed countries. Sustainability in production has become the prime concern in agriculture development. The organic method of farming is the best option to ensure that the air, water and soil around us remain unpolluted, leaving the environment safe for present and future generations.

In many countries exploitative agriculture using industrial inputs has been the norm since the 1960s, in order to cater for an increasing population and to combat the occurrence of famine and natural calamities. Such a system of farming has been causing imbalances in the constituents of biosphere, bioforces, bioforms and biosources. As a result the health of 'Mother Earth' has been deteriorating. Organic agriculture aims to tackle the above concern, and also aims at protecting the environment from continuous decline (Anon. 1998).

4.2 Concept of organic farming

The concept of organic farming is based on an holistic approach where nature is perceived to be more than just an individual element. In this farming system there is dynamic interaction between soil, humus, plant, animal, eco-system and environment. Hence organic farming differs from industrial agriculture as in the latter, biological systems are replaced by technical production systems with liberal use of chemicals (Anon. 1999).

Organic farming improves the structure and fertility of the soil through balanced choice of crops and implementation of diversified crop rotation systems. Biological processes are strengthened without recoursing to chemical remedies, such as synthetic fertilizers and pesticides. In this farming system control of pests, diseases and weeds is primarily preventative, and if required, adopting organic products, which will not adversely affect the environment. Genetically modified organisms are not normally

acceptable because of the manipulations made in their natural set up. Organic matter of various kinds, nitrogen fixing plants, pests and disease resistant varieties, soil improvement practices such as mulching and fallowing, crop rotation, multiple cropping, mixed farming, etc., are freely adopted. In brief, organic farming merges traditional and respectable views on nature with modern insights.

4.2.1 Bio-dynamic agriculture

Bio-dynamic agriculture is yet another approach to organic farming. It is based on anthropsophy on the ideas formulated by the Austrian expert, Rudolf Steiner, in 1924 (Boor 2000). In this system, the maintenance and furtherance of life processes on Earth are achieved by harnessing cosmic energy and various influences of the sun, the stars, the moon and other planets. Bio-dynamic agriculture most often combines animal husbandry and crop production and use of compost and bio-dynamic preparations to revitalize soil and plants and subsequently animals and human beings. Sowing, cultivation and harvesting are timed according to cosmic rhythms.

4.3 Standards and certification

The most significant factors distinguishing organic farming from other methods of sustainable agriculture are the existence of production and processing standards, and certification procedures.

4.3.1 Standards

Standards are developed by private associations, companies, certification bodies or by the State itself. Over one hundred regional, national and international standards have been developed worldwide so far. Several countries are formulating or have adopted rules and regulations on organic farming, processing and certification requirements.

4.3.2 Certification

Most regulations require products that are labelled organic to be certified by an independent body, thereby providing a guarantee that the products have been made according to organic production standards. It is to protect consumers, producers and traders against the use of misleading or incorrect labels. It is also a trading instrument enabling producers to access markets for organic products and obtain premium prices. Moreover, it creates transparencies, as information on certified producing agencies and their products is normally available to the public directly from the package.

Before certification, a detailed inspection by a designated agency is carried out to verify that production and handling are done in accordance with the standards against which certification is done. The certification procedures make it possible to track and control the flow of products from primary and farm level to each stage of manufacturing and ultimately to the finished product for the consumer. This is possible as certification is based on a series of systematic procedures. The farmer, the processor, the trader or whoever is handling the product signs a contract with the certification body. Farmers are required to provide basic information on the farm, such as location and size of fields, crops grown, crop rotation practised, farming method followed, pest and disease control

measures adopted on farm processing carried out, etc., to the certification body. If there is industrial processing to be carried out, details of the processing unit, technology used in processing, sources of organic raw materials, products processed, etc., need to be presented to the certification body. The certification body has to be convinced not only orally but also through records and registers maintained by the producer or operator. Certification is not a one-time procedure. It is carried out continuously on the basis of ongoing monitoring and inspection of farms and processing units.

Though India has a set of organic farmers and a few processing units, local certification bodies accredited to international organizations are only in the formative stage. Hence in India organic products require certification bodies established in other countries, especially in Europe. Of the over 100 certification bodies existing globally, three agencies have opened offices in India. Many Indian organic farmers or their associations avail assistance of these offices for inspection and certification. However, certain individual firms depend on the agencies in Europe and get the inspectors directly from there. Normally inspection and certification costs vary depending on the nature of inspection to be carried out, but it is generally between 0.3 to 1% for most products of high commercial value.

4.4 Quality

To sell organic spices, quality considerations are most important. Since no chemicals are used for fertilization, control of pest and diseases, elimination of weeds and growth acceleration, some buyers fear that the microbial population in the end products could be on the higher side than those prepared conventionally using these inputs. As there is no opportunity for the use of chemicals in crop production, the products should be absolutely free from their residues including pesticides and fungicides. In brief, three important parameters to market organic food are the following:

1. *Quality* – certified organic, which has to be proved by inspection report and certificate issued by authorized inspection and certification agency following approved standards.
2. *Quality* – microbiologically clean, based on results from recognized laboratory.
3. *Quality* – absolutely residue free, authenticated with analytical data on residues from approved laboratory.

In addition to the above, the product should meet fully the product specifications and all parameters relating to sanitary and phyto-sanitary conditions. In other words, organic spices should not only be superior quality-wise in respect of inherent bio-chemical constituents, but they should also be the most safe for human consumption.

4.5 World trade

No reliable published data are available on global trade in organic agricultural products. The International Trade Centre, Geneva has, however, carried out a market survey in Europe (Denmark, France, Germany, The Netherlands, Sweden, Switzerland, Austria and Italy) and in the United States and Japan in 1997. According to this survey, retail sales of organic foods in these markets were estimated at US$11 billion. The survey did not include Australia, New Zealand and other developed countries. Including these countries,

the organic food trade in 1997 would have been over US$12 billion. According to the statistics published by the International Trade Centre, spices are also important organic products marketed globally (Anon. 1999).

Demand for organic spices varies considerably from country to country and in the kind of spices in a particular country. At present, only a few European countries, USA, Canada and Japan are looking for organic spices. However, countries such as Australia, New Zealand and some other European countries may become involved in the organic spice trade because of the increasing awareness of the safety of organic food consumption. Germany has the highest demand for various organic spices. The world import of various organic spices together during 1999 was less than 300 tonnes as assessed from important buyers. Of this, organic black pepper import was more than 50% followed by ginger, nutmeg and clove.

4.5.1 Indian experience

Traditionally, Indian farmers followed organic cultivation methods until the middle of the last century, as they had no other choice. Since the 1960s, many chemical inputs for increasing agricultural production have become available both from domestic production and import. Some of the chemicals imported, particularly for plant protection, were highly dangerous to human health and they left poisonous residues in the soil after application lasting a few decades. The green revolution initiated by importing dwarf and fertilizer responsive wheat and rice varieties led to production programmes using various chemicals profusely in the urge to enhance productivity.

A new trend is being developed in India now to produce various crops, including spices, organically not only to protect the natural environment but also because of the need for having safe agriculture products for human consumption. Accordingly some farmers produce spices by organic methods for their own consumption and also for sale in a limited way in the local markets.

India has established a name in supplying quality organic spices to Europe and USA. The pioneering work in this regard has been by the Peermade Development Society, Peermade, Kerala, India, with the support of the Spices Board of India. A number of organic spices such as black pepper, white pepper, ginger, turmeric, clove, nutmeg and mace have been exported to USA, the Netherlands, Germany and Switzerland since 1998. The Society has over 1200 farmers growing various horticultural crops especially black pepper and other spices in South India. The Society proposes to produce various other spices like vanilla, chilli, coriander, cumin, fennel, fenugreek, etc., through organic cultivation methods in the near future. A centre for research and training of vermicompost production and multiplication and distribution of bio-agents like *Trichoderma* has been set up for supporting farmers in organic cultivation by the Society (George 1999a). There are a few other non-governmental organizations for promoting organic production of herbs in Nilgiri district, black pepper in Wynad district and turmeric and ginger in Phulbani district in India.

4.5.2 Production in other countries

Among other producing countries, Sri Lanka and Indonesia are also in the organic spice production and trade. These countries produce largely organic black pepper. They have established export channels and have entered in the international market for organic spices in recent years.

4.6 Future trends

The organic spice trade is of particular interest to many developing countries growing spices. It should be noted that the initial growth in the organic spice sector is encouraging. Some organic food experts visualize that insufficient supply of organic spices, especially those which are required in large quantities, might become a problem in the next few years (George 1999b).

The future demand for organic spices appears to be bright. Any processed food can only be labelled organic if 95% of the ingredients originate from organic farming. The remaining 5% can be products, which are listed by government regulations, such as EU regulations. Spices are not listed in such regulations and must therefore be of organic origin. Assuming a market growth of 10% in Europe, USA and Japan for organic products, the world demand for organic spices could grow to 57,000 tonnes in the next ten years. This is based on the market size of 570,000 tonnes of conventional spices at that time as reported by the International Trade Centre in their publication, *Imports of Spices into Selected Markets, 1999* (Boor 2000).

Although the overall picture for the organic spice sector is promising, there are a number of potential risks to be borne in mind. There could be occasional oversupply of a given spice leading to erosion of price attraction. Further, other forms or methods of environmentally friendly and sustainable agriculture are likely to result in increased competition in the future. In addition, unfavourable press reports and scare stories on higher microbial contamination in organic foods, in general, as they are not treated with chemicals also cannot be discounted (George 2000).

A few issues which have to be tackled to increase organic production are worth mentioning. They are lack of technical know-how especially on production and processing methods, poor storage and processing facilities, very little market information, insufficient financing and inadequate support from the government agencies. The high cost of certification and the elaborate records to be maintained by small spice farmers to prove their cultivation system organic are also standing in the way of spreading organic spice production. Since demand for organic spices is growing and generally price attractive, it can be visualized that most of the problems would be solved in the near future.

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5

Aniseed

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5.1 Introduction

Source: *Pimpinella anisum* L. (Syn. *Anisum vulgare* Gaertn.; *Anisum officinarum* Mönch; *Apium anisum* (L.) Crantz; *Carum anisum* (L.) Baill.; *Selinum anisum* (L.) E.H.L. Krause; *Pimpinella anisum* (var.) *cultum* Alef; *Sison anisum* Spreng.; *Tragium anisum* Link).[1,2]
Family: *Apiaceae* (= *Umbelliferae*)
Synonyms: Aniseed, Anis seed, Anis, Anise, Sweet cumin
Parts used: Seeds (fruits), oil
Classification:

Division:	Spermatophyta
Subdivision:	Angiospermae
Class:	Magnoliospida
Subclass:	Rosidae
Order:	Apiales
Family:	Apiaceae
Genus:	Pimpinella[3]

Anise is an annual plant that reaches an average height of 30–50 cm. The plant is completely covered with fine hairs. The root is thin and spindle-shaped, the stem up, stalk-round, grooved and branched upward (see Fig. 5.1). In midsummer the thin stems are topped with umbrella-shaped clusters of tiny white flowers, which are heavy enough to make the stems flop. They turn into seedlike fruits. Anise is a cross-pollinating species and is genetically heterogeneous. The fruit is an ovoid-pearshaped schizokarp somewhat compressed at the side. The two-part fruits separate heavily. The carpophore is almost two-piece up to the base. Commercially available aniseed usually contains the whole fruits and occasionally parts of the fruitstalk (see Fig. 5.2). The fruits with the style-foot are 3–5 mm long, 1.5–2.5 mm wide and 2–4 mm thick. Vittae (oil ducts) are almost always present embedded in the fruit wall on the dorsal surface, sometimes in or directly beneath the ridges. The fruits are downy. Their colour is greyish-green to greyish-brown.[4,5]

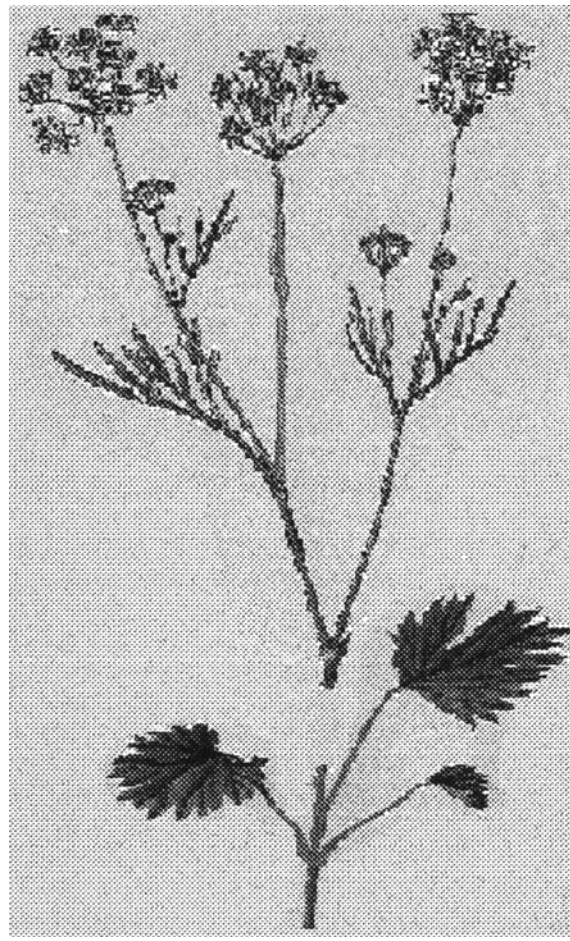

Fig. 5.1 *Pimpinella anisum* L.

5.2 Chemical structure

Anise contains:

- 1–4% volatile oil;
- coumarins: bergapten, umbelliprenine, umbelliferone, scopoletin;
- ca. 8–16% lipids, including fatty acids: 50–70% petroselinic acid (C18:1), 22–28% oleic acid (C18:1), 5–9% linoleic acid (C18:2) and 5–10% saturated fatty acids mostly palmitic acid (C16:0);
- β-amyrin, and stigmasterol and its salts (palmitate and stearate);
- flavonoid glycosides: quercetin-3-glucuronide, rutin, luteolin-7-glucoside, isoorientin, isovitexin, apigenin-7-glucoside (apigetrin) etc;
- myristicin;
- ca. 18% protein;
- ca. 50% carbohydrate and others.

Fatty acids can be obtained by extraction, as in the case of caraway, in the remainders of oil extraction via steam distillation. Lauric acid, which is most important to

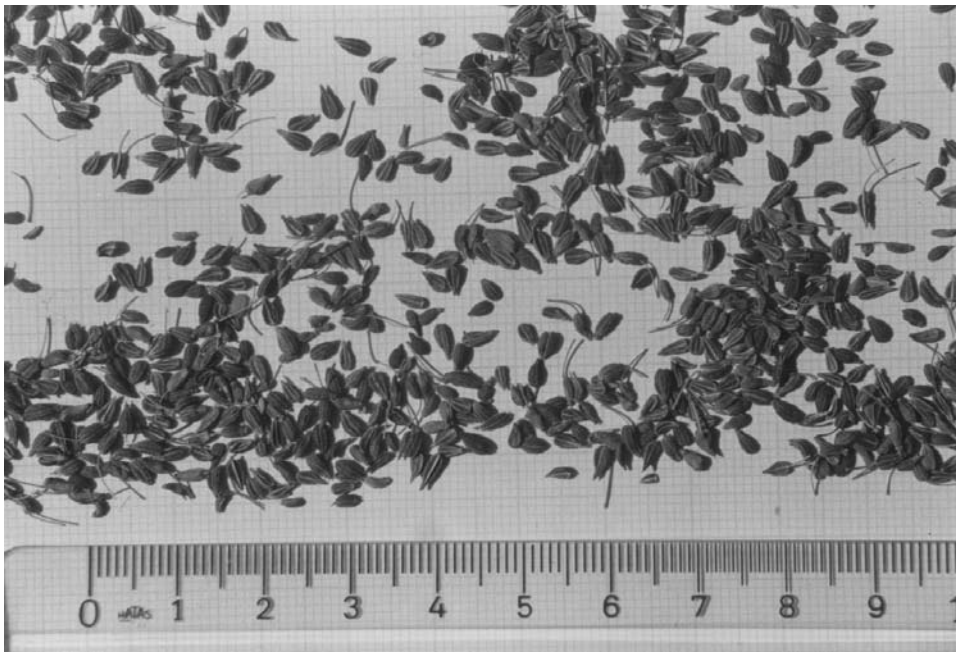

Fig. 5.2 Dried aniseed.

oleochemistry, is obtained from petroselinic acid which is found in high quantities (50–70%) in anise. Fatty oil shows excellent future potential. Successful production of anise seed for economical oil production would probably occur if the seed yields could be improved significantly, and high content of oil and essential oils and large quantity of petroselinic acids could be reached.[6,7]

The major constituent in volatile oil of aniseed is *trans* (E)-anethole (75–90%[7]; 80–90%[8]; 86%[9]; 96–98%[10]; 86–89%[11]; 89–92%[12]). Methylchavicol (estragole) (4.95%[9]; 1.7–3.7%[10]; 3.6–5.5%[11]; 1.0–2.4%[12]), anise ketone (para-methoxyphenylacetone) (0.78%[9]; 0.5–0.9%[11]) and β-caryophyllene are also present, but in lesser relative amounts. Other components in minor concentrations include anisaldehyde, anisic acid (oxidation products of anethole), linalool, limonene, α-pinene, acetaldehyde, *p*-cresol, creosol, hydroquinine, β-farnasene, γ-himachalene and *ar*-curcumene.[7]

5.3 Production

5.3.1 Cultivation

Anise is cultivated in Turkey, Egypt, Spain, Russia, Italy, India, Greece, Northern Africa, Argentina, Malta, Romania and Syria. Anise is primarily exported from Turkey, and also from Egypt and Spain in particular. From an industrial standpoint, the quality differences between anise seed from different origins are not significant and therefore specifications need not limit the spice to a specific country of origin.[13,14,15]

P. anisum requires a warm and long frost-free growing season of 120 days. The plant needs a hot summer to thrive and for seeds to ripen. The reported life zone for anise production is 8 to 23ºC with 0.4 to 1.7 metres of precipitation on a soil pH of 6.3 to 7.3. Anise develops best in deep, rich, well-drained, sandy and calcerous soils. Cold, loamy

and moist soils are unsuitable for the cultivation of anise. During germination anise tolerates salinity up to 160 μm NaCl. The thousand seeds weight of the part-fruits amounts to 1.5 to 3.0 g and should have a minimum purity of 90% and a minimum germination of 70%.

Ripe-fruits seeds germinate relatively quickly. The germination time is 14 days. Only seeds from the previous year's harvest germinate well. Long storage quickly reduces germination vigour: seeds stored for five years will no longer germinate. Planting begins when the soil in the beds is warmed. Optimum soil temperature for germination is 18–21ºC. It is essential to prepare good seedbeds and to create a good contact between the planted seed and the soil because the seeds are small and have low germination percentage (70%). The planting is carried out in spring or autumn depending on the areas it is cultivated. The seeds with a seeding rate of 20–25 kg/ha are sown in rows 20–30 cm apart, at a depth of 1 cm. The plant develops slowly after germination and for the following few weeks it is necessary to control weeds closely. It is recommended to apply fertilizers at a rate of 80–100 kg K_2O and 50–75 kg P_2O_5 per hectare. With nitrogen, it is important to be careful, since excessive nitrogen fertilization results in luxuriant vegetative growth with reduced yields, and increased vulnerability to lodging. 50–100 kg/ha N is normally enough. The small white flowers bloom in midsummer, and seed maturity usually occurs one month after pollination, when the oil content in the dried fruits is about 2.5%. Anise seeds are harvested between from the end of July to the beginning of September, depending on the cultivation areas. Yields of seed up to 500–1000 kg/ha have been achieved. *P. anisum* is recommended in companion planting to repel aphids and cabbage worms. The flowers attract parasitic wasps.[5,6,16,17,18] Constituents in plant volatile oils are known to be useful in pest control. Various authors have reported that vapours of essential oils extracted from anise were found to be toxic to two greenhouse pests, viz. the carmine spider mite, *Tetranychus cinnabarinus* and cotton aphid, *Aphis gossypii* Glov.[19] Sarac and Tunc[20] indicated that the essential oil of anise had a high residual toxicity to adults of *Tribolium confusum*, and was the most repellent to *Sitophilus oryzae* adults in food preference tests.

5.3.2 The production of anise oil

The world production of anise oil amounts to 40–50 tons per annum. The most significant importing countries of anise oil are the USA and France. Russia, Spain and Poland are among the largest producers of anise oil. There is no distillation of anise oil and no production of anethole in many of the countries which cultivate the crop.[21,22,23]

Anise oil is steam distilled from the crushed seeds of the plant *Pimpinella anisum*. The process of steam distillation is the most widely accepted process for the production of essential oils on a large scale. A still is charged with plant material to be processed. Steam is introduced at the base of the still and the crushed anise seeds' volatile elements evaporate with the steam. A condensation process turns this vapour-mix into a liquid form of water and essential oil. The essential oil floats on top of the water and is separated off. The essential oil of aniseed is a colourless to faintly yellow oil which solidifies upon cooling to about 15–19ºC due to the crystallization of anethole.

Oleoresin anise is a yellowish-green to orange-brown fluid oleoresin. Volatile oil content of oleoresin anise is 15–18%. The presence of a large quantity of fixed oil in this product limits its shelf-life and the addition of a permitted antioxidant is advised.[24] Anise and anise oil are widely used as flavouring ingredients in all major categories of foods, including alcoholic and non-alcoholic beverages, frozen dairy desserts, sweets, baked

goods, gelatines and puddings, and meat and meat products. The highest average maximum use levels for anise oil are about 0.06% (570 ppm) in alcoholic beverages and 0.07% (681 ppm) in sweets.[7] Suggested use rate of oleoresin anise is 7.5 to 9%.[24] In Turkey the different types of aniseed spirits are distinguished by their anise seed content: Yeni raki (80 g/L aniseed), Kulup raki (100 g/L aniseed) and Altinbas raki (120 g/L aniseed).[25]

5.3.3 Stability during storage, irradiation and heat processing

Anise has to be stored away from daylight and kept in a dry place in cool conditions (DAB 10 Eur, ÖAB 90, Helv VII). The average loss of the content of the volatile oil has been calculated at 1% of the original content per month. The content of *trans*-anethole decreases from 89% to 73% during a storage of six weeks with the influence of sunlight, while the content of *cis*-anethole increases from 0.8 to 4.5% and the content of anisaldehyde from 0.8 to 7.0%. At the same time additional decomposition products are formed. Investigations on airsealed, grinded aniseed clearly show changes of odour within the first 12 months if the temperature of storage exceeds 5ºC. Because of the sensitivity to light and oxidation it is recommended that the volatile oil of anise is stored in well filled and well closed containers (glass or tin, but not plastic) protected against daylight (DAB 10, BP 88, PFX, ÖAB 90, HELV VII). Moreover, PFX demands a storage temperature below 10ºC and BP 88 a storage temperature below 25ºC. With the influence of daylight, *trans*-anethole is transformed into its more toxic isomer *cis*-anethole.[26]

It is reported that there is an increase in anise ketone, anisaldehyde and anisic acid[9] and decrease in *trans*-anethole[27] of anise oil during long-term storage. Moisture content of the seeds or humidity of the storage atmosphere is the most important parameter to be considered in preserving the desired properties of anise. At high moisture levels deteriorative reactions and off-flavours are inevitable in addition to the increased rate of loss of volatile oil by diffusion. Oxidation reactions are responsible for the loss of oil during storage by converting the components mostly to acids and aldehydes. Also, daylight catalyzes oxidative reactions and increases the rate of deterioration. Extreme variations in the moisture content of the storage atmosphere favour oil evaporation and particularly oxidation.[28] The dimers of anethole (dianethole) and anisaldehyde (dianisoin) are mentioned repeatedly in the literature[14,29,30] and are supposedly responsible for the oestrogenic activity in old drugs and in stored oils under exposure to sunlight, and air could not be found after thorough investigation.[31]

One interesting item to note in this spice is that when the ground product is irradiated, a slightly putrid off odour and flavour results. This contradicts most research that irradiation does not change the chemical properties of a spice when treated. It is possible that it does, in limited cases, change the flavour balance of essential oils.[15] Similarly numerous authors report that volatile oil of anise, extracted after irradiation with 1.5 and 10 kGy γ-rays, contained the most oxygenated compounds, and irradiation caused a general increase in oxygenated compounds at 1 kGy.[32] Farag-Zaied *et al.*[33] indicated that γ-irradiation was effective in decontamination, especially at 10 kGy, but caused losses in the major components of flavour such as anethole, methylchavicol and anisealdehyde in anise.

Thermal treatment at 70ºC for 15 minutes reduced the microbial count and pathogenic microbes, improving the anethole in anise, and washing the spice removed some of the microbes but improved markedly the anise flavour. Thermal and washing treatments may

be of value as simple natural techniques to produce spices with a good flavour and with an acceptable level of contamination.

Bendini *et al.*[34] detected linear, unsaturated hydrocarbons in aniseed samples treated with γ-rays or microwaves. The microwave treatment of aniseeds did not modify the hydrocarbon profile with respect to the untreated samples. In contrast, γ-irradiation gave rise to a series of unsaturated hydrocarbons of which C16:2, C16:1, C17:2 and C17:1 were determined. In most cases, when these products were quantified, their amounts increased with the dose of radiation. C17:1 could be considered as the marker of the γ-irradiation treatment. The essential oil of anise extracted from γ-irradiated and microwaved fruits exhibit antioxidant properties. γ-irradiation and microwave treatments have no effect on the antioxidant properties of essential oil. Essential oil extracted from the γ-irradiated fruits are more effective as antioxidants than those produced from microwaved fruits.[35,36]

5.4 Main uses in food processing

Aniseed's long popularity throughout so many lands stems from its many uses: flavourant, culinary, household, cosmetic and medicinal. While the entire plant is fragrant, it is the fruit of anise, commercially called aniseed, that has been highly valued since antiquity. Aniseed is one of the oldest spices used widely for flavouring curries, breads, soups, baked goods such as German springerle, and Italian biscotti, sweets (e.g. licorice candies, especially aniseed-balls), dried figs, desserts, cream cheese, pickles, coleslaw, egg dishes, non-alcoholic beverage. It is a favourite flavouring for alcoholic drinks in the Mediterranean region, such as French Pastis, Pernod, Anisette, and Ricard, Greek Ouzo, Turkish Raki and Arabian Arak, and also South American Aguardiente, Russian Allasch, Puerto Rican Tres Castillos. Aniseed oil is a component in German Boonekamp, Benediktener, Goldwasser and Spanish Pacharan and Ojen. Anisette combines anise, coriander and fennel seeds in sweet vodka. Anise and anise oils are used in Italian sausage, pepperoni, pizza topping and other processed meat items. Anise is an essential component of Italian anise cake and cookies. All parts of the plant can be used in the kitchen. The flowers and the leaves can be added to fruit salads. Freshly-chopped leaves also enhance dips, cheese spreads, vegetables, or green salads. Mixed into stews and soups, the stem and roots of anise give just a hint of licorice.[6,15,16,18,26]

The essential oil is valuable in perfumery, in dentrifices as an antiseptic, toothpaste, mouthwashes, soaps, detergents, lotions and skin creams, in tobacco manufacture, with maximum use levels of 0.25% oil in perfumes. It is also used to mask undesirable odours in drug and cosmetic products. The oil is used for production of anethole and sometimes as sensitizer for bleaching colours in photography.[7,16,23]

5.5 Functional properties

The pharmaceutical data mentioned in the literature mainly refer to anise oil and anethole. Anethole is structurally related to the catecholamines adrenaline, noradrenaline and dopamine.[37] Anise oil and anethole have a number of functional properties:

- antibacterial
- antifungal

- antioxidant
- stimulant, carminative and expectorant.

The antibacterial activities of the essential oil distilled from *Pimpinella anisum* against *Staphylococcus aureus*, *Streptococcus pyogenes*, *Escherichia coli* and *Corynebacterium ovis* were evaluated. Against *S. pyogenes*, aniseed oil was equally effective in the pure state and at dilution up to 1:1000. Against *C. ovis*, aniseed oil was equally effective at dilutions up to 1:100 and at higher dilutions.[38] The inhibitory properties of anise essential oil, alone or in combination with either benzoic acid or methyl-paraben, against *Listeria monocytogenes* and *Salmonella enteriditis* were investigated. *S. enteriditis* was particularly sensitive to inhibition by combinations of anise essential oil with methyl-paraben. *L. monocytogenes* was less sensitive but exhibited significant reductions in growth in response to combinations of essential oil with methyl-paraben.[39]

Kubo[40] reported that anethole, a naturally occurring phenylpropanoid extracted from aniseed, exhibited a broad antimicrobial spectrum and the antifungal activity (against *Candida albicans*) of two sesquiterpene dialdehydes, polygodial and warburganal (extracted from *Polygonum hydropiper*), was increased 32 fold when combined with low concentrations of anethole. In a study of the volatile oil from aniseed, significant antifungal activity against members of the genera *Alternaria, Aspergillus, Cladosporium, Fusarium* and *Penicillium* was recorded at concentrations of 500 ppm, the active constituent having been identified as anethole.[41] Anethole also inhibits growth of mycotoxin producing *Aspergillus* species in culture. Anethole has been reported to be mutagenic in Ames *Salmonella* reversion assay. Anethole, anisaldehyde and myristicin (in aniseed), along with d-carvone (present in *P. anisum* plant), have been found to have mild insecticidal properties.[7] Pharmacological studies were carried out in rats and mice, and anise oil showed significant antipyretic activities in rats.[42] Curtis[43] reports that synthetic versions of compounds in herbs and spices such as *trans*-anethole have inhibitory and lethal activity against food spoilage yeast *Debaromyces hansenii*.

There is some evidence of anise oil's effectiveness as an antioxidant. Gurdip *et al.*[44] investigated the antioxidant activity of essential oil from spice materials on stored sunflower oil and found that anise oil possessed excellent antioxidant effects, better than those of synthetic antioxidant, butylated hydroxytoluene.

Anise oil is reported to be carminative and expectorant. The reputed lactogogic action of anise has been attributed to anethole, which exerts a competitive antagonism at dopamine receptor sites (dopamine inhibits prolactin secretion), and to the action of polymerized anethole, which is structurally related to the oestrogenic compounds stilbene and stilboestrol. Anethole is also structurally related to the hallucinogenic compound myristicin. Bergapten, in combination with ultraviolet light, has been used in the treatment of psoriasis.[37] Anise oil is used as carminative, stimulant, mild spasmolytic, weak antibacterial, and expectorant in cough mixtures and lozenges, among other preparations. It can be used internally for dyspeptic complaints and externally as an inhalant for congestion of the respiratory tract. The whole, crushed, or ground crude drug can be used for infusion, and other galenical preparations; e.g. several instant teas as powders containing aqueous extracts of aniseed, or as tea paste, some preparations with micro-encapsulated anise oil. Anise seed and anise oil are subjects of German official monographs; 3.0 g of seed or 0.3 g of essential oil (mean daily dose) allowed as a bronchial expectorant for upper respiratory tract congestion and as gastrointestinal spasmolytic.[7,31]

Anise may have other potential health benefits. The effect of the beverage extracts anise on absorption of iron was tested in tied-off intestinal segments of rats. Results

showed that the beverage of anise promoted Fe absorption.[45] Preparations containing 5–10% essential oil are used externally.[7,31] The oil added to an ointment helps in cases of aches of muscles and neuralgia.[6] Olfactory masking with aniseed oil decreased aggression and prevented the decrease in milk production in dairy cattles.[46] It is reported that anethole stimulates hepatic regeneration in rats, and also shows spasmolytic activity. Chemically it is used as a precursor in the manufacture of anisaldehyde. Occurring in the essential oil of *P. anisum*, *p*-anisaldehyde has fungistatic activity; *p*-cresol is a disinfectant agent and cresols are used in veterinary practice as local antiseptics, parasiticides and disinfectants; hydroquinone has antibacterial, antitumour, antimitotic and hypertensive activities. It is cytotoxic to rat hepatoma cells. Uses include a depigmentor, an antioxidant and a photographic reducer and developer.[47]

In traditional medicine anise is reportedly used as aromatic carminative, stimulant and expectorant; also as oestrogenic agents to increase milk secretion, promote menstruation, facilitate birth, increase libido, and alleviate symptoms of male climacteric.[7] Aniseed is traditionally regarded as an aphrodisiac. Externally, the oil may be used as an ointment base for the treatment of scabies. The oil by itself will help in the control of lice and as a chest rub for bronchial complaints. The oil is often mixed with oil of *Sassafras albidum* for skin parasites and with that of *Eucalyptus globulus* as a chest rub.[18]

5.6 Toxicity and allergy

Aniseed contains anethole and estragole which are structurally related to safrole, a known hepatotoxin and carcinogen. Although both anethole and estragole have been shown to cause hepatotoxicity in rodents, aniseed is not thought to represent a risk to human health when it is consumed in amounts normally encountered in foods.[37] Anise and oil of anise are generally regarded as safe for human consumption.

The toxicity and cancerogenity of anethole are controversial. Anethole has two isomers (*trans* and *cis*), the *cis* (Z) isomer being 15–38 times more toxic to animals than the *trans* (E) isomer.[7] The major component of the natural volatile oil of anise (80–96%) is *trans*-anethole, which is most likely non-cancerogenic. *Trans*-anethole will be accompanied by *cis*-anethole (maximum 0.3–0.4%), which is not caused by distillation, but exists naturally in anise seeds. In case of storage without protection of daylight the forming of *cis*-anethole is possible. Synthetic *trans*-anethole contains higher quantities of toxic *cis*-anethole compared to natural *trans*-anethole and therefore it is not used in food processing. Cases of intoxication with the volatile oil of anise are not known.[26] Current United States Pharmacopeia (USP) and Food Chemical Codex (FCC) specifications for anethole do not require differentiation between the isomers.[7]

Aniseed may cause an allergic reaction. It is recommended that the use of aniseed oil should be avoided in dermatitis, or any inflammatory or allergic skin conditions.[37] Patients with an allergy to pollen are often suffering from 'spice-allergy' like celery, carrot, etc. Skin-prick tests with anise extracts in several cases result in positive allergic reactions.[26] Freeman[48] reports an atopic man who experienced cutaneous allergy and periorbital edema after preparing and eating fresh dill. The patient reported here demonstrated reactive skin tests and positive radio allergo sorbent test (RAST) to other members of the *Umbelliferae* including aniseed in addition to dill. Similarly Fraj *et al.*[49] describe a case of occupational asthma induced from aniseed dust sensitization. A skin-prick test carried out with 13 spices showed positive reactions only to aniseed extract.

When consumed in sufficient quantities, anise oil may induce nausea, vomiting,

seizures and pulmonary edema. Contact of the concentrated oil with skin can cause irritations.[16] Anethole has been reported to be the cause of dermatitis (erythema, scaling and vesiculation) in some people.[7] Compared with star anise however, the sensitization effect of anise oil is lower.[26]

5.7 Quality and regulatory issues

The recommended moisture limits from the American Spice Trade Association (ASTA) is 10% in whole and in ground anise. Ash and acid insoluble ash should be no greater than 6.0% and 1.0%, respectively.[15] According to BHP 1983:[31] foreign organic matter, not more than 2%; other fruits and seeds, not more than 2%; total ash, not more than 10%; acid-insoluble ash, not more than 2.5%. The minimum content of volatile oil of anise is 2% (BHP 1983; Ph. Eur, 2).[31] Anise oil is a colourless to pale yellow, strongly refractive liquid, having the characteristic odour and taste of anise. It should contain 84–93% *trans*-anethole (major component and typical carrier of odour and flavour) and 0.5–6.0% methylchavicol (=estragole, which smells like anise but does not have its sweet taste) (HPLC profile Ph. Eur.).[14]

Anise oil is frequently adulterated with the lower priced star anise oil, which, according to several Pharmacopoeiae, is also considered 'anise oil'. Star anise (*Illicium verum* Hook f.) is the dried fruit of a tall evergreen tree, which is native to southern China and northern Vietnam. The profile of star anise oil is similar to that the *Pimpinella* oil and the two are equally acceptable and interchangeable in use. But, strictly from the flavouring viewpoint, anise oil (*P. anisum*) is undoubtedly superior to star anise oil (*I. verum),* the latter having a somewhat harsher odour. Pharmacopoeiae therefore demand the specification of the plant of origin out of which the anise oil was extracted (whether from aniseed, *P. anisum* or star anise, *I. verum*, which can be determined). This is obviously for the sake of consumer protection, since star anise oil is substantially cheaper than the oil extracted from anise. Characteristic of genuine aniseed oil is the presence of up to 5% of the 2-methylbutyryl ester of 4-methoxy-2-(1-propenyl)-phenol (= pseudoisoeugenyl 2-methylbutyrate). On the other hand, fruit oil of *I. verum* is characterized by the presence of Foeniculin. The provenance of an oil can be determined by detection of each of these two substances. Star anise oil further differs from *P. anisum* oil by its content of several terpene hydrocarbons (THC) as well as its content of 1,4-cineol. This may explain why star anise oil does not reach the flavour quality of aniseed oil.[14,26,31,50] Other adulterants are synthetic anethole and fennel oil. The latter can be detected by a change in the optical rotation. Much cheaper synthetic anetholes are also available but some carry a risk of toxicity, which precludes their use in food and drinks.[50,51] A further criterion of quality is its solidification point which sinks with decreasing content of anethol. The solidification point of officinal anise oil lies between +15ºC and +19ºC (Ph. Eur.). Pure anethole becomes fluid above +23ºC and solidifies at +21ºC. All Pharmacopoeiae recommend checking physical properties like specific gravity, refractive index, optical rotation and temperature of solidification in order to get hints about the purity of anise oil. Table 5.1 lists physical properties according to different sources. The specifications of the limits as mentioned in the Pharmacopoeiae vary slightly. Anise oil has to be dissolvable in 1.5 to 3.0 times its volume of EtOH 90% (DAB 10, NFXVII, ÖAB 90, Helv VII). This test is useful to exclude adulterations by fats, oils and mineral oils.[26]

Italian anis may be confused (in former times more often, nowadays very rarely) occasionally with poisonous fruits of *Conicum maculatum* L. (hemlock). Morpho-

Table 5.1 Physical properties of anise volatile oil according to different sources

Properties	Turkish anise[11] volatile oil	Food chemical[52] codex specification	Pharmacopoeiae[26]	ISO[53]
Specific gravity (20ºC)	0,990	0,978–0,988	0,979–0,994 (DAB10)	0.980–0990
Refractive index (20ºC)	1,558	1,553–1,560	1,553–1,561 (DAB10)	1.552–1.559
Solidification point	19ºC	> 15ºC	> 15ºC (BP 88)	+ 15ºC to + 19.5
Optical rotation (20ºC)	–	−2º to + 1º	−2º to + 1º (BP 88)	−2º to + 5º

logically, hemlock fruit can be recognized by the undulate (especially in the upper part of the fruit) ridges. Crushed fruits that are moistened with a potassium hydroxide solution should not smell like mouse urine (coniine). Adulteration with parsley or dill fruits can be detected readily by their smaller size and missing hairs. Nearly all anise fruits currently traded are impurified with up to 1% coriander fruits.[14,31] Adulteration of powdered aniseed or anise oil can be rapidly and reliably determined by direct mass spectroscopy via the 'marker' compound pseudoisoeugenyl 2-methyl-butyrate which only occurs in genuine 'anise oil'; as little as 0.2–1.4% can be detected in the presence of 94% anethole, without the necessity of its having to be separated or the sample specially prepared.[31]

In the USA, aniseed is listed as GRAS (Generally Regarded As Safe; §182.10 and §182.20). Aniseed is used extensively as a spice and is listed by the Council of Europe as a natural source of food flavouring (category N2). Anise seed and anise oil are subject to different pharmacopoeial Monographs: Aust., Br., Cz., Egypt., Eur., Fr., Ger., Gr., Hung., It., Neth., Rom., Rus., and Swiss.[37] Aniseed is covered by the following: Anise DAB 10 (Eur), ÖAB90, Helv VII, Pimpinella BHP83, Aniseed Mar29. Anise oil is covered by: DAB 10, BP88, NFXVI, Essentia anisi Hisp IX, Huile essentielle d'anis PFX, Anisi aetheroleum ÖAB90, Helv VII, Anise Oil BPC79, Mar 29 (All pharmacopoeias mentioned under Monographs except Hisp IX additionally allow *Illicium verum* Hook as plant of origin). Homeopathic guidance includes: *Pimpinella anisum*, ethanol. Decoctum hom. HAB1, Anisum hom. HAB 34, Anisum hom. HPUS88.[26]

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Bay leaves

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6.1 Introduction

The commodity, traded as sweet bay leaf, and true, Roman, or Turkish laurel, is derived from the leaves of *Laurus nobilis* L. (Family – Lauraceae). Because of the similarity in the leaves, several other trees are also variously known as: West Indian bay tree (*Pimenta racemosa),* Cherry laurel (*Prunus laurocerasus),* Portugal laurel (*Prunus lusitanica),* Laurel of the southern states (*Prunus caroliniana*), the Laurel or Mountain laurel of California (*Umbellularia californica*). However, the leaves of true *L. nobilis* must not be confused with other laurels. *L. nobilis* is a native of the Mediterranean and grows spontaneously in scrubland and woods in Europe and in California. It is widely cultivated in Europe, America and in Arabian countries from Libya to Morocco (Bailey 1963, Anon. 1962).

The flavouring properties of *L. nobilis* have been known since antiquity. In biblical times, the bay was symbolic of wealth and wickedness, and in the classical world heroes and victors were decorated with a laurel wreath. In addition to being a very well known culinary herb, the leaves and fruits of *L. nobilis* are used medicinally throughout the world. Infusions or decoctions made from these materials have diaphoretic and carminative effects and also serve as a general gastric secretion stimulant. Laurel oil or butter obtained from the fruits (berries) of *L. nobilis* is a vital ingredient of laurin ointment, a popular medicine for rheumatism and gout and for the treatment of spleen and liver diseases. It also finds application in veterinary medicine (Anon. 1962; Duke 1989; Wren 1975; Francesco and Francesco 1971).

L. nobilis is an evergreen shrub, or more rarely a tree attaining a height of 15–20 m. The smooth bark may be olive green or of reddish hue. The luxurious, evergreen leaves are alternate with short stalks, lanceolate or lanceolate oblong, acuminate, 5–8 cm or longer and 3–4 cm wide, coriaceous, pellucid-punctate, and with revolute, entire wavy margins; the upper surface is glabrous and shiny, olive green to brown and the lower surface is dull olive to brown with a prominant rib and veins. The flowers are small, yellow in colour, unisexual and appear in clusters. The fruits (berries) are cherry-like, succulent, purple to black in colour, ovoid, coarsely wrinkled and contain a single seed

with loose kernel. The dried fruits are drupaceous, ovoid, about 15 mm long and 10 mm wide. The outer surface is glabrous, shining, nearly black and is coarsely wrinkled owing to the shrinkage of the narrow succulent region beneath the epidermis. The remains of the style appear as a small point at the apex and a small scar at the base marks the point of attachment of the fruit to the thalamus. The endocarp is thin and woody and the testa is adherent to its inner surface. The entire pericarp is about 0.5 mm thick. The kernel of the seed consists of two large plano-convex cotyledons and small superior radicle; it is brownish-yellow, starchy and oleaginous, with an aromatic odour and aromatic and bitter taste (Bailey 1963; Wallis 1960; Francesco and Francesco 1971).

The cross-section of the leaf shows epidermal cells with thick cuticle; the epidermal cells in surface view are sinous, pitted and thick walled. The lower epidermal walls are more curvilinear and distinctly beaded. The stomata are present only on the lower surface, singly or in pairs. The mesophyll of the leaf is distinctly represented by two layers of parenchymatous palisade cells and a region of spongy parenchyma containing scattered spheroidal oil reservoirs, fibro-vascular and collenchymatous tissues. The leaf has characteristic fragrance when crushed and its taste is bitter and aromatic (Wallis 1960; Bagchi and Srivastava 1993).

6.2 Cultivation, production and processing

Sweet bay is propagated by seeds or preferably by cuttings. From a well ripened wood, cuttings of about 7.5 to 10 cm length are put in sharp sand either under bell-glasses or in glass cases. The rooted cuttings are placed in small pots containing fairly rich sandy loam with good drainage, and then can be put in a hot bed, with gentle bottom heat where they will make a good strong growth. *L. nobilis* stem cuttings produce roots better in July/August, under Mediterranean conditions, than in other seasons, although the optimal rooting period can be extended by bottom heating from May until September (Raviv 1983a). Ligneous, subapical stem cuttings of bay laurel have a higher rooting percentage than herbaceous apical cuttings, probably due to water deficit in the latter, moisture sufficiency may be critical due to the very long rooting period of four to five months (Raviv 1983b).

Rapid and efficient rooting of *L. nobilis* occurs at a root medium temperature of 20ºC to 30ºC, especially during the winter when, if not heated, both the medium and air temperatures are less than 15ºC in the Mediterranean region (Raviv and Puticvsky 1983). After that, they may be planted in nursery beds with rich sandy soil and good drainage. In one growing season, the plants may attain a height of 1 to 1.5 m. At the end of the growing season and long before the cold season the young plants together with their stakes are kept in well lit and ventilated sheds, and temperature is kept just above freezing. These plants are kept in close rows and watered once or twice a week. The plants are taken out during the spring season and either potted or plunged in nursery. The rich peaty soil with plenty of water and congenial moist atmosphere near the sea coast are favourable conditions for fast and luxriant growth (Bailey 1963). It also grows well under the partly shaded conditions in gardens or orchards.

The leaves of *L. nobilis* are plucked and dried under shade for use as a flavouring material in a variety of culinary preparations, especially in French cuisine. The leaves contain an essential oil of aromatic, spicy odour and flavour which can be isolated by steam distillation. The oil is a valuable adjunct in the flavouring of all kinds of food products, particularly meats, sausages, canned soups, baked goods, confectionery, etc.

The oil replaces the dried leaves to great advantage because it can be dosed more exactly and therefore gives more uniform results than the dried leaves (Guenther 1953).

Laurel berries contain about 1% of an aromatic volatile oil and 25 to 30% fat. The separated fat is the *Olecum lauri expressum* of commerce. The pure fat is of dull green colour, granular and has an aromatic odour. The expressed oil is used in stimulating liniments and in veterinary practice (Wallis 1960).

Currently, two types of essential oils are traded internationally under the name 'bay oil', although they are entirely unrelated to each other. The West Indian bay oil or bay leaf oil is distilled from the leaves of the tree of *Pimenta racemosa*, which is found on the various islands of the West Indies, but most particularly in Dominica. The Turkish bay oil or laurel leaf oil is distilled from the leaves of *L. nobilis*. The sources of the bulk culinary bay leaves are Turkey and the Balkan countries, and in small quantities from France. The annual production level of the genuine *L. nobilis* oil is only about 2 tons. It is marketed mainly in Western Europe, largely in Germany and the Netherlands (Anon. 1986).

6.3 Chemical composition

A good deal of work on physico-chemical characterisation and chemical composition of essential oils of different parts of *L. nobilis* have been reported. The reported values of physico-chemical constants and chemical constituents identified are provided in Table 6.1. The studies carried out so far on the bay oil indicate the influence of geographical origin of variety and harvest season on the chemical composition. The chemical composition of the flower essential oil is quite different from other parts of the plant, namely leaves, stem bark and stem wood (Fiorini *et al.* 1997). The earlier studies were mostly carried out by chemical methods (Nigam *et al*. 1958) but recent GC-MS and GLC analyses has made possible the isolation and characterisation of a number of compounds more accurately and efficiently (Nigam *et al.* 1992; Fiorini *et al.* 1997). The chemical structure of some of the important constituents are provided in Figure 6.1. The presence of 1,8 cineole in appreciable amounts makes the oil of bay leaves an important perfumery item (Pruidze 1971).

6.4 Functional properties

Although the dried bay leaves and their essential oil are mainly used as a spice and food flavouring agent, the bay oil also finds use in folk or traditional medicines of different countries, for the treatment of a number of diseases. Recent studies have shown that it has the following functional properties:

- antimicrobial and antifungal characteristics
- hypoglycaemic properties (in the control of diabetes)
- antiulcerogenic properties.

The essential oil of *L. nobilis* has been found to be active against *Staphylococcus aureus*, *Escherichia coli*, *Shigella flexnerii* and *Salmonella typhi*, pathogens of the intestinal tract (Syed *et al.* 1991). The *L. nobilis* has also been noted to possess anti-fungal activity (ies), (Rahari Velomanana *et al.* 1989; MacGregor *et al.* 1974).

The hypoglycaemic activity of bay leaf extracts has also been reported (Ashaeva *et al*. 1984). Bay leaves potentiated the action of insulin in glucose metabolism (Khan *et al.*

Table 6.1 Physico-chemical properties and chemical constituents of essential oil extracted from different parts of *Laurus nobilis* of varying geographical origins

S. No.	Geographical origin of the resource material	Plant part and its essential oil content	Physical characteristic(s) determined	Chemical constituent(s) identified	Reference(s)
1.	NA[a]	NA	Yellowish brown unpleasant odour, d 0.9278 $(\alpha)^{22}$ d −120º, hd 1.4730, soluble in ethyl alcohol 1:90	α-pinene, eugenol, phellandrene	Rattu and Maccioni (1952)
2.	NA	Fruits, 1%	—	pinene, cineole, lauric acid, alcohols and sesquiterpenes	Rattu *et al.* (1953)
3.	NA	Fruits	n_D^{30} 1.4898, d_{20}^{20} 0.9218, $(\alpha)_D^{20}$ −18.9º, acid no. 5.92, sap. no. 67.94	cineole (12.8%), free alcohols 10.7%, esters (chiefly Mecinnamate 17.9%), free cinnamic acid (1.3%), free phenols (2.0%), terpene hydrocarbons (15.4%), and different carbonyl compounds and sesquiterpenes.	Nigam *et al.* (1958)
4.	Idzhevanskii, Armenia, Noemberyam-skii, Armenia	Leaves	d 2.5–3.3, (α) 3.8–3.1. d 0.924–1.4687, n_D 0.9416–1.4664	—	Melkumyan and Khurshundyan (1959)
5.	NA	Fruits, 4.1%	n_D^{20} 1.4898, d_{20}^{20} C.9218, $(\alpha)_d$ −18.9º. Acid value 5.92, sap. value 67-94, sap. value (after acetylation) 99.80	Carbonyl compounds 11.48%, alkali soluble (by vol) 9%, α-pinene, citral terpineol, Me-cinnamate, cinnamic acid, caryophyllene, sesquiterpenes hydrocarbons	Nigam *et al.* (1958)
6.	NA	Information on plant part not mentioned 2.5%	NA	α-pinene, camphene, sabinene, limonene, carene and 1,8-cineole (35%)	Teisserie (1966)

Table 6.1 Continued

S. No.	Geographical origin of the resource material	Plant part and its essential oil content	Physical characteristic(s) determined	Chemical constituent(s) identified	Reference(s)
7.	NA	NA	NA	α-pinene, camphene, β-pinene, sabinene, 3-carene, α-phellandrene, α-terpinene, myrcene, α-limonene, β-phellandrene, γ-terpinene, *p*-cymine, terpinolene and ocimene	Teisserie *et al.* (1966)
8.	Czechoslo-vakia	Leaves	NA	β-pinene, camphene, myrcene, limonene, *p*-cymene, β-phellandrine, β-selinene, γ and δ-cadinene	Chow *et al.* (1965)
9.	Kazakistan	Shoot, 0.5%	NA	α-pinene, β-pinene, camphene, l-sebinene, β-myrcene, α and β-phelandrene, 1-limonene, *p*-cymene, 1-8-cineole, acetic, propionic, butyric, caproic, caprylic, pelargonic and enanthric acid in phenolic in terpens fraction eugenol,	Goryaev *et al.* (1966)
10.	Greece	Leaves, 1.0%	NA	α-pinene, camphene, β-pinene, sabinine, myrcene, β-phellandrene, d-limonene, cineole, γ-terpinine, p-cymene, terpinelene, camphor, linalool, α-terpineol, terpenyl acetate, β-selinene, methyl eugenol, terpin-eugenol and acetyl eugenol	Giuliana and Stancher (1968)
	Turkey	Leaves, 0.8%	NA		
11.	NA	NA	NA	α-pinene, α-thujene, camphene, β-pinene, sabinene, myrcene, α-phellandrene, limonene, β-phellandrene, 1,8-cineole, γ-terpinene, *p*-cymol, linalool, terpinene-4-ol, eugenol, methyl eugenol, trepenyl formate	Kekelidze *et al.* (1977)

12.	Italy	NA	NA	α-thujene (5.9%), β-pinene (20.1%) 1,8 cineole (37.3%) *p*-cymene (traces), α-terpineol (2.2%), terpenyl acetate (10.6%), methyl eugenol (0.3%)	Hector and Retamar (1978)
13.	Turkey	Leaves	NA	*Cis*-thujzen-4-ol (a new compound)	Novak (1985)
14.	Greece	Leaves	NA	1,8 cineole and α-terpenyl acetate (major component) pinocarvone and (E)-pinocarveol (new compounds)	Tucker *et al.* (1992)
15.	Uttarkhand, India	Fruits, 5%	d_{36} 0.923, $n_D^{35°}$, 1.4960, $[9]_D^{28°}$ – 5.73°, acid value, 3.34 and ester value, 25.86, ester value after acetylation – 54.68	1,8 cineole (28.4%), methyl cinnamate, (20.1%), α-phellandrene (10.1%), α-pinene (9.3%), α terpenol (5.8%), sabinene (4.9%), α-thujene (3.8%), β-humulene (3.3%), linalool (2.3%), camphor (2.2%), and α-gurujunene 2.2%	Nigam *et al.* (1992), Appendino *et al.* (1992)
16.	India	Petroleum ether extract of fruits	NA	10-hydroxyoctacosanyl tetradicanoate, l-do co sanol tetradecanoate and 11-gaveeramanthin, dehydrocostus lactone, costunolide, zalu zanin and sesquiterpene alcohol	Garg *et al.* (1992)
17.	Toulouse, France	Flowers, 0.18%	NA	(E)-ocimene and sesquiterpenic compounds – β-carophyllene, viridio-florene, β-clemene, germacrene-D-4-ol and germacrene-D	Fiorini *et al.* (1997)
		Leaves, 0.57%		1,8 cineole, linalool, methyleugenol and α-terpenyl acetate	
		Stem bark 0.68%		1, 8 cineole	
		Stem wood, 0.07%		α-terpinyl acetate, methyl eugenol and α-copaene	

a = NA, information, not available,

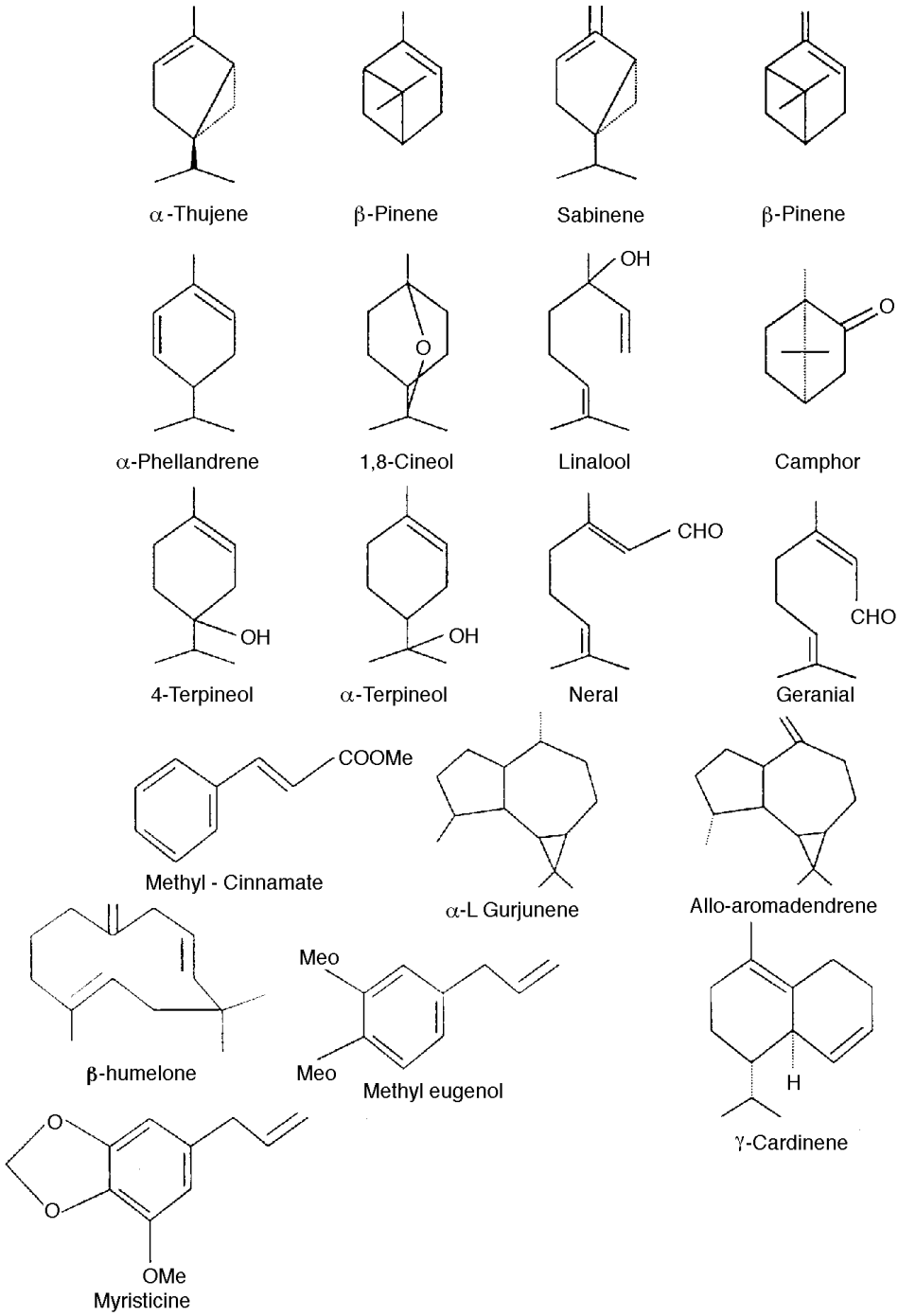

Fig 6.1 Structures of some important chemical constituents of essential oil of bay leaves

1990) and reduced glucose transport (Gurman *et al.* 1992). The administration of 200 and 600 mg/kg doses of the ethanolic extract of leaves of *L. nobilis* produced a significant decrease in blood glucose levels in diabetic rabbits (Yanardag and Can 1994).

The possible antiulcerogenic activity of *L. nobilis* seeds was tested on experimentally (ethanol) induced gastric ulcers in rats. The results indicated antiulcerogenic activity for 20 and 40% aqueous extracts as well as for the oily fraction of the seeds. In acute toxicity studies, the aqueous extract was found safe with LD50 compared to oil LD50 at 0.33 ml/kg body weight (Afifi *et al*. 1997).

Bay has also been reported as having a number of other properties. The methanolic extract from the leaves of *L. nobilis* inhibited the elevation of blood ethanol level in ethanol loaded rats. The bioassay-guided separation resulted in the isolation of costunolide, dehydrocostus lactone, and santamarine as the active constituents. The α-methylene-γ-butyrolactone structure was found to be essential for the preventive effect on ethanol absorption. In addition, the retardation of gastric emptying seemed to be partially involved in the preventive effects (Matsuda *et al.* 1999).

The effects of aqueous extracts of leaves and flowers of *L. nobilis* on adult snail and embryo (*Biomphalaria glabrata*) have been studied. Results obtained have shown a degree of toxicity on the embryos starting at a concentration of 125 ppm. The flower extract appeared to be more effective. Cephalic and shell malformations were found in embryos treated with both leaf (50 ppm) and flower (25 ppm) extracts. The LD90 value on adult snails was estimated as 340 ppm for flower extract and 1900 ppm for leaf extract (Rey and Kawano 1987). Cockroach repellant activity has also been found in bay leaves (Verma and Meloan 1981).

The antioxidant properties of bay have been discussed by Lagouri and Bouskou (1995).

6.5 Toxicity and allergenicity

Bay leaves and their essential oil do not appear to have any significant toxicity. However, sporadic reports have indicated that bay leaves may cause allergic contact dermatitis (Asakawa *et al.* 1974; Cheminat *et al.* 1984; Goncalo and Goncalo 1991) perhaps induced by one or more sesquiterpene lactone. Certain bay leaf samples of Mexican origin had been detected to be infested with gastrointestinal disease causing *Clostridium perfringens* spores @ <100 to 450 Cfu/g (Rodriguez-Romo *et al.* 1998).

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7

Black pepper

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7.1 Introduction

Among the spices, black pepper is the king. It is the most important, most popular and most widely used spice in the world. It has extensive culinary uses for flavouring and preserving processed foods and is important medicinally. Of the total spices traded internationally pepper accounts for about 34% (throughout this chapter, pepper is used to mean black pepper, unless otherwise stated). South West India is the traditional home of this important spice, particularly the Western coastal regions of South Peninsular India (the Malabar Coast).

Black pepper was the first oriental spice to be introduced into the Western world, and was well known among the Romans and Greeks. In the middle ages pepper assumed great importance in Europe. Its use resulted in revolutionary changes in Western cooking: together with other spices, pepper helped to improve flavour and preservation of food became easier. Pepper was also used in medicine, as a carminative and febrifuge, for aiding in digestion, and in curing the common cold.

7.2 Production and international trade

The genus *Piper* comprises about 1200 species, about 60% of which occur in central and northern South America. The other important regions are South and South-East Asia. Pepper is now grown in tropical zones such as the Asia Pacific region, mainly India, Indonesia, Malaysia, Sri Lanka, Thailand, China, Vietnam and Cambodia. Outside the Asia Pacific region the crop is distributed in Brazil, Mexico, Guatemala, etc., totalling about 26 countries (see Table 7.1). The total global area under pepper production is around 404,000 ha producing around 180,000 tonnes of pepper annually.

In 1950, 70% of world pepper cultivation was concentrated in India, but this had gone down to 46% by 1991 and production from 66% to 30%. India's share of the world market has come down from 56% to 23% in the same period. At the same time pepper production in other countries made remarkable progress. Currently India ranks first in

Table 7.1 Pepper production in producing countries 1996 to 1999 (in tonnes)

Country	1996	1997	1998	1999
Asia & Pacific	**153,988**			
India	60,000	60,000	65,000	75,000
Indonesia	39,200	43,291	56,250	44,500
Malaysia	12,000	18,000	19,000	21,500
Vietnam	20,000	25,000	22,000	30,000
China P.R.	8,000	NA	NA	12,000
Thailand	9,773	5,183	5,313	7,000
Sri Lanka	3,000	4,470	6,771	4,740
Cambodia	2,000	NA	NA	NA
Brunei Darus	15			
South Pacific	**168**			
Fiji	150			
Samoa	6			
Micronesia	12			
Latin America	**21,690**			
Brazil	19,500	18,000	17,000	22,000
Mexico	1,250			
Guatemala	380			
Honduras	400			
Saint Lucia	160			
Africa	**4,565**			
Madagascar	2,500			
Malawi	700			
Zimbabwe	700			
Benin	150			
Kenya	300			
Côte d'Ivoire	100			
Cameroon	65			
Ethiopia	–			
Zambia	50			
Total	**180,411**			

Source: Proc. Pepper Tech. Meet 1996. International Pepper Community (IPC) Jakarta Publications, 1997, 1998, 1999.

area followed by Indonesia and Brazil, while in production India ranks first followed by Indonesia and Vietnam. As far as productivity is concerned, Thailand ranks first (4089 kg/ha) and India is in the last position (311 kg/ha). The present status of area, production, productivity and export of pepper in the world is presented in Table 7.2. Export and percent production exported is presented in Table 7.3.

In India pepper is cultivated in an area of around 181,500 ha with an annual production that fluctuates between 60–80,000 tonnes annually (75,000 t in 1999 and 60,000 t in 2000). Kerala state is the major producer accounting for 72% of the crop, followed by Karnataka (22%) and the remainder is from Tamil Nadu, Andhra Pradesh and Goa. India started export of value added products of pepper in the 1970s. Until 1970 only small quantities of spice oil and oleoresin were manufactured and exported from India. Until that time pepper was exported only in the raw form and in bulk. Though there has been demand for diversified products of pepper, even now Indian export of black pepper is mainly in bulk and raw form.

Table 7.2 Area production and productivity and export of black pepper in major growing countries 1996/1999

Country	Area ('000 ha)	Production ('000 t)	Productivity kg/ha	Export ('000 t)	Production ('000 t)	Export ('000 t)
	1996				1999	
India*	197.50	60.00	304	35.07	75.00	47.32
Indonesia	128.67	39.20	305	34.00	44.50	35.53
Malaysia	8.80	12.00	364	14.80	21.50	21.59
Brazil	21.00	19.50	929	15.30	22.00	19.53
Sri Lanka	12.09	3.00	248	2.10	4.74	3.74
Thailand	2.39	9.77	4089	0.50	7.00	0.86
IPC countries	**370.36**	**143.47**	**–**	**101.78**	**174.74**	**128.57**
Vietnam	17.00	20.00	1176	75.00	30.00	28.00
China PR	11.18	8.00	716	5.00	12.00	
Madagascar	4.00	2.50	625	2.00	2.00	
Mexico	1.30	1.25	962	2.50		
Non-IPC	**33.48**	**31.75**		**84.50**	**44.00**	**28.00**
Total	403.93	175.22		136.28	218.74	156.57

Source: IPC 1997. Pepper Statistical Year Book 1995–96, IPC Jakarta, IPC Publications, 1999.
* Department of Economics and Statistics, New Delhi.

India, Brazil, Malaysia, Indonesia, Vietnam and Thailand are the main suppliers to the world market. Major importers of Indian pepper include USA, Russia, Canada, Germany, Italy, Netherlands, France, Japan, Morocco, Poland, UK, Canada and Saudi Arabia. The annual world export during 1988–93 ranged from 172,000–242,000 t. The value of world exports from 1988–93 ranged from US$270–569 million per year. The imports ranged from 174,000 to 216,000 t, valued at US$273–658 million. The export of pepper shows considerable change in recent years due to changes in the geographical composition from the 1970s and 1980s (Table 7.3). The projected world consumption of pepper by 2010 is estimated to be around 230,000 mt from the present production and consumption of around 180,000 mt. The consumption of pepper has undergone a steady increase in most consuming countries (Table 7.4) and the trend is expected to continue.

7.3 Description

Black pepper is obtained from mature fruits of *Piper nigrum* L., a perennial woody evergreen climber, native to the evergreen forests of the Western Ghats of South India (see Fig. 7.1). Under cultivation pepper vines are trailed over supports – either living trees or other supports, as columns 5–6 m tall and 1.0–2.0 m in diameter. The climbing woody stems have swollen nodes having clinging roots at each node, which helps in anchoring the vine to the support trees (standards). Pepper plants exhibit dimorphic branching, having two different types of branches: the straight upward growing (monopodial) main stem and orthotropic shoot climbing and remaining vegetative, adhering to the support with short adventitious roots at nodes. From the axils of leaves of orthotropic shoots, lateral shoots (plagiotropic branches) grow, and they have a sympodial habit of growth, having shorter internodes and without adventitious roots.

Table 7.3 Export ('000 t) and (%) production exported from major producing countries, 1995–99

Country	1995		1996		1997		1998		1999	
	Export	% production exported	Export	% production exported	Export	% production exported	Export	% production exported	Export	% production exported
Brazil	21.25	106.25	15.30	78.46	13.36	74.22	17.25	101.47	19.54	88.81
India	24.54	44.62	35.07	58.45	36.08	60.13	33.25	51.15	47.32	63.09
Indonesia	56.13	95.14	34.00	86.73	32.51	74.05	39.56	70.33	35.53	79.84
Malaysia	13.98	107.54	14.80	123.33	24.56	73.29	17.83	93.84	21.59	100.00
Thailand	0.91	8.31	0.50	5.12	0.51	9.85	0.50	9.42	0.86	12.28
Sri Lanka	2.40	64.34	20.10	48.72	3.28	73.38	5.49	81.09	3.74	78.90
IPC countries	**119.20**	**73.78**	**101.78**	**70.29**	**110.30**	**74.05**	**113.88**	**67.25**	**128.58**	**73.58**
Vietnam	15.00	75.00	15.00	75.00	23.5	94.00	22.00	100.00	28.00	93.33
China (PR)	5.00	60.39	5.00	42.25						
Madagascar	1.27	50.80	2.00	80.00						
Mexico	2.50	200.00	2.50	200.00						
Non-IPC countries	**23.77**	**74.21**	**24.50**	**69.01**						
Total	142.97	73.81	136.28	70.04						

Source: IPC, 1997, Pepper Statistical Year Book 1995–96, IPC, Kuningan, Jakarta. IPC Publications, 1999.

Table 7.4 Pepper consumption in developed countries (in grams)

	Countries	1975	1980	1990–95 (average)
1	Denmark	102	128	194
2	Germany	131	170	190
3	Belgium	90	127	181
4	USA	117	144	168
5	The Netherlands	94	91	151
6	Austria	97	141	150
7	France	107	124	138
8	Sweden	90	96	122
9	Canada	100	87	112
10	Switzerland	121	139	112

In such branches, as the growth proceeds, the terminal bud gets modified into an inflorescence (spike) and further growth is continued by the axilliary bud (see Fig. 7.2).

The pepper plant has a delicate root system and around 75% of the roots are confined to an area of 75 to 100 cm radius and depth (Jayasree *et al.* 1988). Inflorescence of pepper

Fig. 7.1 General view of a pepper vine.

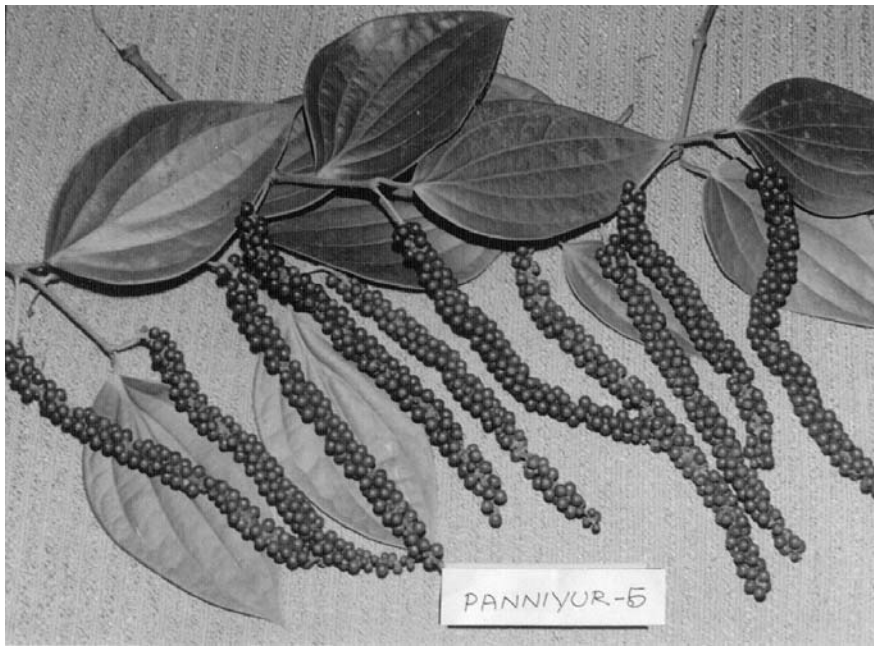


Fig. 7.2 Spikes of pepper.

is a pendent spike (catkin) appearing opposite the leaf on plagiotropic branches. Spikes vary in length in cultivars, being 3–15 cm long with 50–150 flowers. The flowers are very minute, white to pale yellow in colour, arranged spirally on fleshy peduncles. The species is naturally self-pollinated, and pollination is by geitenogamy. The dispersal of pollen is aided by the presence of water droplets. The fruit is a single seeded drupe, but is often called a berry, sessile, small, usually globular, having fleshy pericarp and hard endocarp. The fruits are spherical in shape in most cases, obovate in a few and oblong in others. Fruits are green when young, changing to red on ripening.

Black pepper has a somatic chromosome number of 2n = 52, and is believed to be of hybrid origin. The meiosis is usually normal, and fertility high. Among the cultivars cv. *Vadakkan* is a triploid and has a somatic chromosome number of 2n = 78. The related species have chromosome numbers ranging from 2n = 26–132.

7.4 Cultivars and varieties: quality issues

The cultivars of black pepper have originated from the wild types. More than hundred cultivars are known and a few of them are still popular (Ravindran *et al*. 2000). The traditional pepper growing tracts have their own popular cultivars. Cultivar diversity is richest in the state of Kerala. Studies carried out in pepper growing belts identified specific cultivars/varieties suitable for different agroecological regions as well as for growing under different cropping systems. The important popular cultivars in India and other countries are given in Tables 7.5 and 7.6.

Black pepper is predominantly a self-pollinated crop. Variability for yield and quality characters are seen frequently among cultivars and within the same cultivar. Systematic research efforts in the last three decades has resulted in the release of 12 high yielding

Table 7.5 The important popular cultivars in India

Aimpiriyan, Arakkulam Munda, Blankotta, Cheriyakaniyakadan, Jeerakamundi, Kalluvally, Karimunda, Kottanadan, Karimkotta, Kuthiravally, Narayakodi, Neelamundi, Perambra Munda, Perumkodi, Thomankodi, Valiakaniyakadan, Vellanamben, etc., from Kerala and Uddagere, Doddigae and Malligesara from Karnataka.
Improved varieties: Panniyur 1, 2, 3, 4, 5, 6 and 7, Sreekara, Subhakara, Panchami, Pournami and PLD-2

Table 7.6 The popular cultivars in other countries

Brazil: Kuching (Singapura), Panniyuri 1
Malaysia: Kuching, Sarikei, Miri
Indonesia: Bangka, Banjarmasin, Belantung, Beng Kayang, Chunuk, Chunuk Kernuga (CK_2), Djambi, Duantebei, Kerenci, Kernuga (CK_1), 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)
Sri Lanka: Ceylon
Madagascar: Sel.IV.1, Sel.IV.2
Thailand: Antique (Buffaloes Horning), Ban keow, Prang Thi, Prang Thi Bai yick, 'thick leaf'.

superior lines of black pepper through clonal selection, selection in OP progenies as well as through hybridization followed by selection in segregating populations.

The quality of black pepper is as important as yield and depends on the contents of piperine and essential oil. Variability of quality characters in black pepper has been investigated and cultivars were classified based on quality parameters (Gopalam and Ravindran 1987). Evaluation studies of germplasm collections resulted in identifying high piperine, oil and oleoresin types. Quality variations among common cultivars are given in Table 7.7. Essential oil varies from 0.4 to 7.0% while piperine from 2.0 to 7.4% among cultivars.

7.5 Cultivation

Though pepper is essentially a tropical plant requiring a hot humid climate, it can be grown in a wide range of environmental conditions. The characteristic and most suitable climate requirement for pepper are high rainfall, uniform temperature and high relative humidity, which is typical of the hot and humid tropical region. The plant requires equable climate, rainfall of 2000–4000 mm together with a mean temperature of 25–32ºC and RH of 65–95%. Pepper grows successfully between latitudes 20ºN and 20ºS, from sea level up to an altitude of about 1200 m above MSL. The sub-mountain tracts of Western Ghats of India up to about 1000 MSL are ideal for pepper cultivation. Rainfall in May–June initiates the flushing and flowering process, but once the process starts, there should be good precipitation until fruit development is over. Long spells of dry weather are unfavourable for the crop growth. Pepper yield is significantly correlated with the rainfall received during the first half of May and the cumulative total rainfalls in the second half of the year. In the pepper growing regions of Sarawak, Indonesia, Thailand and Vietnam the rainfall is well distributed having practically no drought period. Pepper grows in a wide range of soils with a pH of 4.5 to 6.9. The most favourable soil types are deep well drained brown red latosols or andosols, but the crop can grow well in deep

Table 7.7 Quality composition of important cultivars (values on dry weight basis)*

SL.No	Cultivar	Volatile oil % (v/w)	Oleoresin % (w/w)	Piperine % (w/w)	Starch % (w/w)
1	*Arikottanandan*	4.75	12.90	4.50	24.66
2	*Arakkulam munda*	4.75	9.84	4.40	36.18
3	*Blankotta*	5.12	9.35	4.26	25.20
4	*Ceylon*	3.75	3.50	7.60	15.66
5	*Cheriyakaniakkadan*	3.75	9.05	3.95	24.84
6	*Chumala*	2.25	5.45	3.30	46.62
7	*Doddigya*	2.50	7.10	2.85	36.00
8	*Kalluvally*	3.25	8.80	4.24	31.50
9	*Kalluvally (PTB)*	0.40	10.90	4.65	29.00
10	*Kalluvally type I*	3.00	8.44	5.40	20.70
11	*Kaniakkadan*	4.75	11.60	6.00	12.42
12	*Kottanadan*	2.50	17.80	6.60	23.40
13	*Karimunda*	4.00	11.00	4.40	39.60
14	*Karuvilanchy*	3.50	9.70	4.30	27.00
15	*Kumbbakodi*	4.50	14.90	7.60	18.20
16	*Kuthiravally*	4.50	14.90	5.97	14.04
17	*Munda*	4.75	7.00	5.60	22.70
18	*Mundi*	3.50	7.50	3.60	23.40
19	*Narayakkodi*	4.00	10.85	5.40	24.50
20	*Nilgiris*	5.50	15.50	6.05	23.60
21	*Palulauta*	3.00	7.60	3.60	19.26
22	*Panniyur I*	3.50	9.52	3.60	35.10
23	*Perumkodi*	3.00	8.60	4.00	28.80
24	*Perumunda*	4.00	8.00	7.40	26.64
25	*Shimoga*	2.50	7.20	4.56	17.64
26	*Sullia*	4.00	6.80	3.60	20.70
27	*TMB II*	2.50	10.80	5.80	32.60
28	*Uthirankotta*	4.75	8.55	3.92	28.80
29	*Vally*	2.50	6.53	4.90	16.02
30	*Aimpiriyan*	2.63	15.70	4.69	–
31	*Udhakara*	3.82	8.61	2.36	–
32	*Thommankodi*	5.98	13.77	2.77	–
33	*Sreekara*	7.00	13.00	5.10	–
34	*Subhakara*	6.00	12.40	3.40	–
35	*Panchami*	3.40	12.50	4.70	–
36	*Pournami*	3.35	13.80	4.10	–

*Ravindran *et al.* (2000b).

sandy clay as well if provided with mineral nutrition and adequate drainage. Purseglove *et al*. (1981) suggested that the ideal soil for pepper growing is well distributed alluvium rich in humus with pH above 5.5 or 5.8.

The cultivation system of pepper varies in different pepper growing countries. In India pepper is cultivated mostly in homestead gardens as a mixed crop and is seldom grown as pure plantation. In Sarawak, Thailand, Vietnam, Brazil, etc., pepper is grown mostly as a sole crop. Pepper vines are trailed on supports called standards, either live (on trees) or dead (such as concrete/wooden poles). Field planting of pepper vine is 3 × 3 m or 3 × 2 m (in sloppy lands). A spacing of 2.5 m × 2.5 m accommodating 1600 standards/ha or 3 × 3 m (1100 vines/ha) are commonly used. Before planting, the land is cleared, tilled and hoed. For planting pepper, pits of 50 × 50 × 50 cm are dug on the northern side of the standard at a distance of 15 cm. The pits are then filled with a mixture of top soil + FYM

+ Neem cake + bone meal, etc. Rooted cuttings are transplanted in the field during the rainy season. The best period for planting vines is at the beginning of the monsoon. Where the possibility of water stagnation exists, planting is carried out in August, or cuttings are planted on mounds.

Post planting management practices include tying vines to standards, pruning, shade regulation, basin management including mulching, weeding, intercropping, etc. During the initial growth phase shoots are tied to supports, and plants shaded. Mounds are to be maintained for dense rooting and to avoid water stagnation during the rainy season. Pruning is necessary to maximize production of fruiting lateral branches; but in India, Sri Lanka and Indonesia pruning is not practised. After three years plants grow to almost 2.5 m tall, have bushy appearance with many branches and a close canopy. In Sarawak, Malaysia, different pruning methods are adopted which result in thick bushy growth of plants.

A novel technique for raising black pepper and maintaining it in bush form has been developed. Instead of allowing the pepper vines to climb on supports (standards) as is usual, it can be grown as a bush so that it can be accommodated in homestead and terrace gardens. The fruiting lateral branches of any variety can be used to make saplings which start flowering in the same year and continue to yield throughout the year. Under good management a bush pepper plant grown in pots can yield an average of 100–150 g of dry pepper per pot/year (see Fig. 7.3).

It is essential that adequate and balanced fertilizers are applied to maintain the soil fertility and productivity of vines. A fertilizer dose of 100:40:140 NPK/ha is recommended for medium fertile soil in India. Depending upon soil nutrient status and location, specific fertilizer recommendations are also available. In the first two years the plants are to be supplied with half the dose of fertilizers in four equal applications. In India fertilizers are normally applied only twice a year, at the onset of monsoon and towards the end of the rainy season. In Sarawak, Thailand, etc., owing to the well-distributed rainfall, 4–5 fertilizer doses are given and this is one reason for the greater productivity in these countries. Pepper is grown as a rainfed crop in the majority of areas. Irrigation of vine during summer is beneficial. Diagnostic Recommendation Integration System (DRIS) was developed to quantify precisely the nutrients for sustainable black pepper production (Sadanandan 2000).

Insect pests and diseases are major constraints responsible for low productivity and crop loss in all pepper producing countries. Pepper is affected by several diseases that are caused by fungi, bacteria, virus and mycoplasma besides nutritional disorders. Diseases of pepper have been reviewed recently by Anandaraj (2000). Among the pepper diseases the serious ones are the foot rot caused by *Phytophthora capsici* f. *piperi*; pepper yellows (or slow decline) complex caused by the burrowing nematode (*Radopholus similis*) and *P. capsici;* and the virus disease (little leaf) caused probably by a Badna virus (see Anandaraj 2000, Ramana and Eapen 2000). Management programmes have been evolved to contain these diseases (Anandaraj 2000). In Brazil, *Fusarium* infestation is common and has led to large scale devastation of pepper, though the *Fusarium* etiology is still doubted. Infestation by insect pests is another factor responsible for low productivity of pepper in major growing countries. Insect pests of pepper have been reviewed recently by Devasahayam (2000). Pepper is infested by 56 general species of insects damaging various parts of vines such as root, stem, shoot, leaves, spikes and berries. However, depending on the severity and extent of damage, pollu beetle, top shoot borer, leaf gall thrips and scale insects could be considered as major pests. Successful chemical control measures are available for the management of insect pests.

Fig. 7.3 Bush pepper developed from a plagiotropic shoot.

Pepper vines attain full bearing from the fifth year onwards, though they commence yield from the second year. Light showers during May–June are considered beneficial for fruit set. Pepper plant starts flowering during May–June with the onset of the south west monsoon and harvesting is usually in December–January. Variation in maturity pattern depends on factors such as variety, rainfall, altitude, ambient temperature, etc. Pepper fruits mature in about 6–8 months after flowering. The period generally coincides with dry weather in India. The season of flowering and harvest of pepper varies from country to country (see Table 7.8).

Harvesting is carried out when one or more berries in some spikes turn orange to red colour. Entire spikes are picked when fruits are fully mature but still green (see Fig. 7.4). Pepper quality depends on maturity, processing and post-harvest handling. Advances made in the diversification of products and value added produce have necessitated harvesting of berries at different stages of maturity, to be regulated depending on the various end uses (Govindarajan 1977) (see Table 7.9).

Table 7.8 Season of black pepper flowering and harvest (Lawrence 1981)

Country	Flowering	Harvest
India	May–June	November–February (plains)
Bangka (Indonesia)	January–March	July–September
Lampong (Indonesia)	December–January	June–August
Brazil	February	August–November
Sri Lanka	November–December	March–May
Cambodia	June	January–March
Thailand	June–August	February–March
Sarawak	December–January	April–July

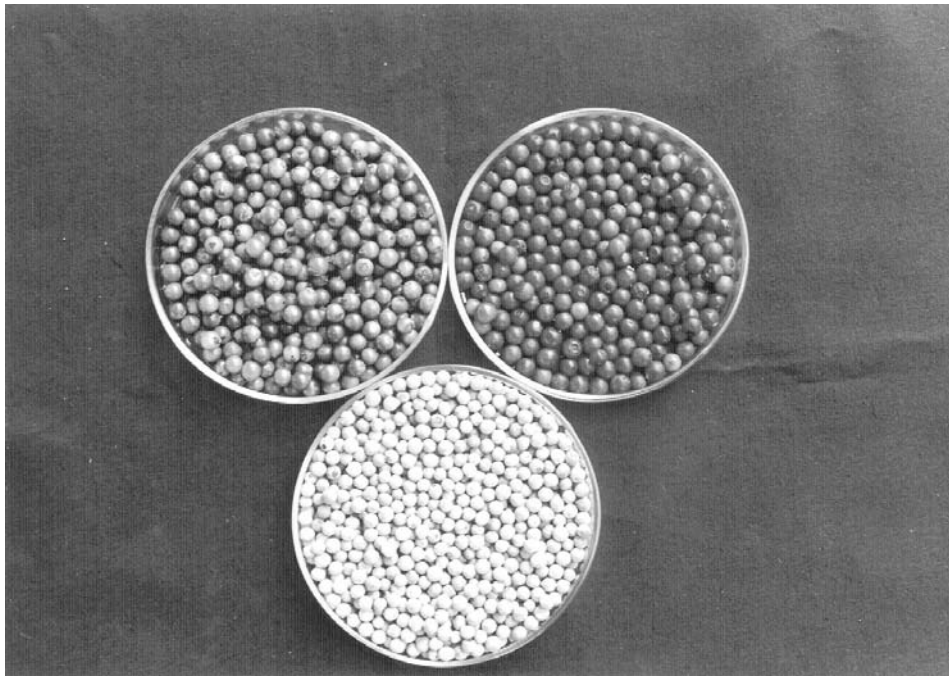


Fig. 7.4 Pepper berries (top left: fresh berries; top right: fully ripened berries; bottom: white pepper).

7.6 Handling after harvest

Post-harvest handling is crucial to get a high-quality product. The harvested spikes are kept in bags for 12–24 hours or heaped and covered overnight for a brief fermentation which makes despiking easy. The spikes are then threshed manually by rubbing or trampling underfoot or by using mechanical threshers of various types. Mechanical threshers are used only by large growers. Recently small-scale threshers are becoming popular in Sarawak and Indonesia. For a more detailed discussion on the topic, see Risfaheri and Nurdjannah (2000) and Zachariah (2000). Fruits separated by threshing are sun dried. Sometimes a blanching process is carried out before drying, by dipping fruits (in a wire basket) in boiling water for two minutes. The fruits are then spread out on the floor for drying. Blanching improves colour and also removes dust and adhering microbial contamination. Drying is done in the open sun in most cases. A black topped

Table 7.9 Pepper harvesting for various end products (Govindarajan 1977)

Products	Maturity at harvest
White pepper	Fully ripe
Black pepper	Fully mature and nearly ripe
Canned pepper	4–5 months after fruit set
Dehydrated green pepper	10–15 days before full maturity
Oleoresin	15–20 days before full maturity
Oil	15–20 days before full maturity
Pepper powder	Fully mature with maximum starch

Table 7.10 Size variations of different pepper cultivars/varieties

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

Table 7.11 Average composition of dried pepper (Pruthi 1993)

Content	% of composition
Moisture	8.7–14.0
Total nitrogen	1.5–2.6
Volatile ether extract	0.3–4.2
Non volatile extract	3.9–11.5
Alcohol extract	4.4–12.0
Starch	28.0–49.0
Crude fibre	8.7–18.0
Piperine	1.7–7.4
Total ash	3.6–5.7
Acid soluble ash	0.03–0.55

cement floor is the best for sun drying. Mechanical, electrical and solar dryers are also used for rapid drying. Dry recovery percentage varies among cultivars and growing conditions; usually the recovery ranges from 28–38%. After proper drying the moisture content should be around 10% only (for details see Ravindran 2000).

It is ideal to grade green berries using a mesh to remove the light berries and pinheads and classify based on size. Dried berries are also graded based on size. The size variations usually encountered with different cultivars/varieties are shown in Table 7.10. The average composition of dried pepper is given in Table 7.11 (Pruthi 1993). The dried pepper is cleaned to remove extraneous matter like dirt, grit, stones, stalks, etc., and berries are graded according to their size or density before packing.

7.7 Chemical structure

The quality of pepper is contributed by two components:

- piperine that contributes the pungency
- volatile oil that is responsible for the aroma and flavour.

Oleoresin of black pepper, produced by solvent extraction of dried powdered pepper, contains both aroma and pungency principles. Thus the chemistry of pepper is the chemistry of its essential (volatile) oil and piperine. The chemistry of pepper has been reviewed by Guenther (1952), Govindarajan (1977), Parmar *et al.* (1997) and Narayanan (2000).

7.7.1 Piperine

Piperine was first isolated by Oersted (1819) as a yellow crystalline substance. This alkaloid is the major pungent component present in pepper. In addition, five minor alkaloids possessing pungency have been identified in pepper extracts.

Piperine ($C_{17}H_{19}O_3N$; m.p 128–130ºC) is a weak base, which on hydrolysis with HNO_3 or aqueous alkali yields a volatile base piperidine ($C_5H_{11}N$). The acidic product of hydrolysis is piperinic acid ($C_{17}H_{19}O_4$). The structure of piperine is established as peperinic acid piperidide.

Piperinic acid exists in four isomeric forms: 2 *trans* 4 *trans* (piperine); 2 *cis* 4 *trans* (isopiperine); 2 *trans* 4 *cis* (isochavicine) and 2 *cis* 4 *cis* (chavicine). The synthesis of the isomers was carried out by Grewe *et al.* (1970) The structure of piperinic acid and its isomeric forms are given in Fig. 7.5. The three isomers of piperine are only weakly pungent. Piperine is highly sensitive to light. Irradiation of piperine in alcoholic solution produces a mixture of isopiperine and isochavicine.

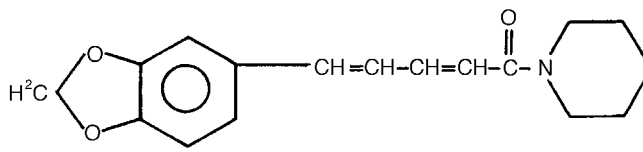
Piperine can be estimated by UV spectrophotometry by measuring the absorption maxima at 342–345 nm of a solution in benzine or ethylene dichloride. As piperine in dilute solution is highly photosensitive the solution should not be exposed to direct light.

Five analogues of piperine were isolated and characterized by various workers (Govindarajan 1977, Narayanan 2000). They are piperettine, piperanine, piperylin A, piperolein B and pipericine. The chemical structures of these analogues are given in Fig. 7.6. Parmar *et al.* (1997) listed the following alkaloids in addition to the piperine group of alkaloids mentioned above: brachymide B, guineesine, retrofractamide A, sarmentine, sarmentosine and tricholein.

7.7.2 Essential oil of pepper

The essential oil of pepper is a mixture of a large number of volatile chemical compounds. The aroma is contributed by the totality of the components. More than 80 components have been reported in pepper essential oil (Gopalakrishnan *et al.* 1993) (see Table 7.12). Only the important components are mentioned below (Narayanan 2000).

1. *Monoterpene hydrocarbons and oxygenated compounds.* This group includes: camphene, δ^3-carene, ρ-cymene, limonene, myrcene, *cis*-ocimene, α-phellandrene, β-phellandrene, α-pinene, β-pinene, sabinene, α-terpinene, γ-terpinene, terpinolene, α-thujene. Among them the major components are α-pinene, β-pinene, sabinene and limonene. The chemical structures of these compounds are given in Fig. 7.7. There



The structure of piperine

5(3,4-methylene dioxyphenyl) penta 2,4 -- dienoic acid piperidide

2 - trans,	4 - trans	Piperine
2 - cis,	4 - trans	Isopiperine
2 - trans,	4 - cis	Isochavicine
2 - cis,	4 - cis	Chavicine

Fig. 7.5 The structure of piperine.

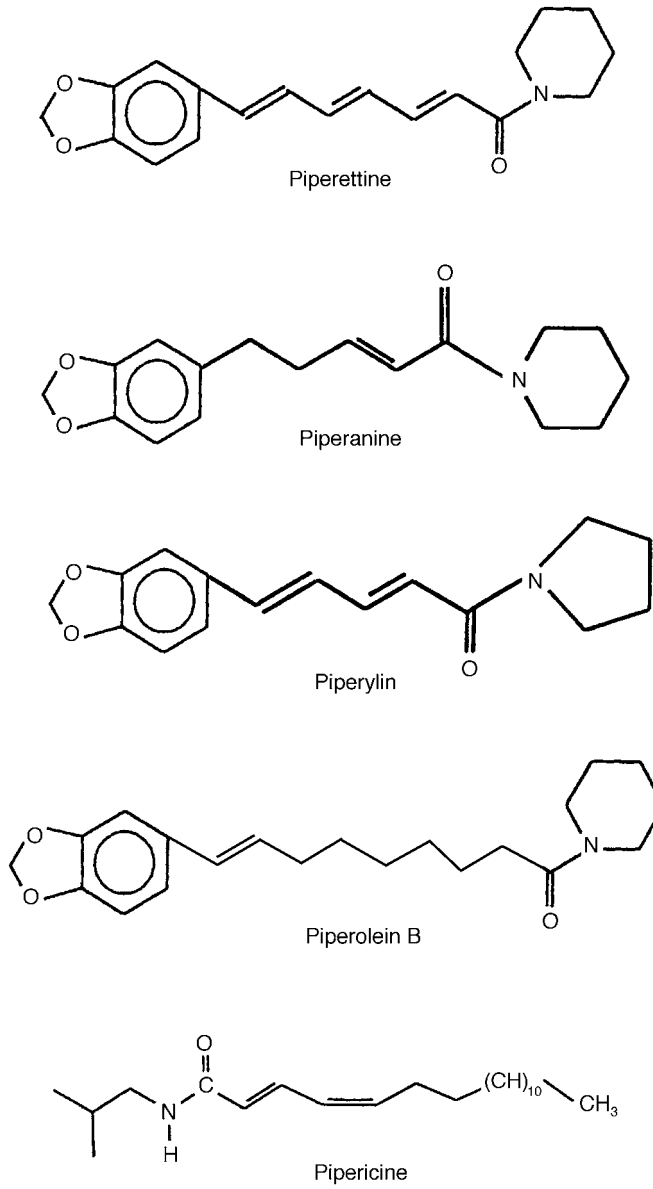


Fig. 7.6 Chemical structures of five analogues of piperine: piperettine, piperanine, piperyline A, piperolein B and pipericine.

are many oxygenated monoterpenoid compounds present in pepper essential oil, about 43 are known. They are: borneol, camphor, carvacrol, *cis*-carveol, *trans*-carveol, carvone, carventanacetone, 1,8-cincole, cryptone, ρ-cymene-8-ol, ρ-cymene-8-methyl ether, dihydrocarveol, dihydrocarvone, linalool, *cis*-menthadien-2-ol, 3,8,(9)-ρ-menthadien-1-ol, 1(7)-ρ-menthadien-6-ol, 1(7)-ρ-menthadien-4-ol, 1,8(9)-ρ-menthadien-5-ol, 1,8(9)-ρ-menthadien-4-ol, *cis*-ρ-2-menthen-1-ol, myrtenal, myrtenol, methyl carvacrol, *trans*-pinocarveol, pinocamphene, *cis*-sabinene hydrate, *trans*-sabinene hydrate, 1-terpinen-4-ol, 1-terpinen-5-ol, α-terpeneol,1,1,1,4-trimethylcyclo-hepta-2, 4-dien-6-ol, phellandral, piperitone,

Table 7.12 Comparative chemical composition of four pepper genotypes

Peak No.	Compound	Kovats index		Percent composition			
		Exp	Ref	1	2	3	4
1	α-thujene	931	938	0.73	1.26	1.59	0.91
2	α-pinene	943	942	5.28	6.18	5.07	5.32
3	Camphene	954	954	0.14	0.18	0.14	0.13
4	Sabinene	975	976	8.50	13.54	17.16	1.94
5	β-pinene	981	981	11.08	10.88	9.16	6.40
6	Myrcene	986	986	2.23	2.30	2.20	8.40
7	α-phellandrene	990	1002	0.68	0.20	–	2.32
8	δ-3-carene	1005	1009	2.82	0.18	–	1.03
9	α-terpinene	1008	1010	–	–	0.39	1.13
10	ρ-cymene	1018	1020	–	0.18	0.07	9.70
11	(Z)-β-ocimene + β-phellandrene	1022	1025/ 1025	–	0.15	0.23	0.37
12	Limonene	1039	1030	21.06	21.26	22.71	16.74
13	(E)-β-ocimene	1045	1038	0.18	2.84	0.30	0.17
14	γ-terpinene	1055	1057	0.01	0.49	–	0.03
15	Trans-sabinene hydrate	1057	1060	0.14	–	0.30	0.19
16	Terpinolene	1066	1074	0.10	0.20	0.22	0.08
17	Trans-linalool oxide (furanoid)[ti]	1082	1082	0.03	0.18	–	0.08
18	Unidentified	1085	1087	0.24	0.22	0.26	0.60
19	Linalool	1092	1092	0.22	0.22	0.46	0.28
20	Cis-p-menth-2-en-1 -ol+cis-p-menth-2, 8-diene-1-ol	1117	1111/ 1120	0.04	0.04	0.05	0.02
21	Trans-p-menth-2-en-1-ol	1128	1128	0.01	0.01	0.01	0.01
22	Citronellal	1134	1137	0.02	0.03	0.03	0.01
23	p-menth-8-en-1-ol	1154	1156	0.03	t	–	T
24	Borneol	1159	1164	t	t	t	T
25	Terpinen-4-ol	1170	1175	0.19	0.32	0.52	0.18
26	α-terpineol	1183	1185	0.10	0.17	0.12	0.07
27	Dihydrocarveol	1187	1188	0.01	–	0.02	0.02
28	p-menth-8-en-2-ol	1199	1208	–	0.01	0.02	0.02
29	Trans-carveol	1206	1209	0.01	0.01	–	0.02
30	Cis-carveol+carvone	1224	1222/ 1228	0.01	0.03	0.03	0.03
31	Piperitone	1245	1247	0.04	t	0.03	T
32	Carvone oxide*	1261	1261	0.01	0.01	–	0.01
33	Myrtenol	1277	1281	0.20	0.04	0.11	0.04
33(a)	Unidentified	1287	–	0.02	–	–	–
33(b)	Unidentified	1299	–	0.02	t	t	–
34	α-terpinyl acetate	1334	1333	0.86	1.22	1.33	1.05
35	Neryl acetate	1346	1345	0.20	0.07	0.05	0.13
36	Geranyl acetate	1364	1363	0.12	0.01	0.09	0.11
37	α-cubebene/δ-elemene	1376	1381	3.25	0.26	0.16	2.56
38	α-copaene	1384	1398	0.82	0.49	0.44	0.71
39	β-elemene	1403	1400	0.09	0.09	0.06	0.05
40	β-caryophyllene	1429	1428	21.59	27.70	23.29	21.19
41	Trans-∝-bergamotene	1431	1436	0.31	–	–	0.28
42	α-humulene	1435	1437	0.21	0.20	0.11	0.29

43	(E)-β-farnesene	1445	1448	0.08	0.22	0.03	0.13
44	α-amorphene	1451	1451	1.51	1.53	1.54	1.28
45	α-guaiene	1455	1454	0.11	0.07	–	0.10
46	Clovene[ti]	1460	–	0.14	0.07	0.07	0.13
47	Germacrene-D[ti]	1469	1469	0.04	0.03	0.04	0.26
48	Ar-curcumene	1474	1475	0.26	0.12	0.04	0.29
49	β-selinene	1480	1477	0.64	0.87	1.37	0.63
50	α-selinene	1483	1484	0.07	0.12	0.48	0.14
51	γ-muurolene	1489	1486	0.73	0.93	0.16	0.58
52	(E,E)-α-farnesene	1492	1494	0.72	–	0.47	0.72
53	β-bisabolene + α-bisabolene[ti]	1498	1496	4.25	2.15	3.10	0.49
54	δ-guaiene[ti]	1515	1502	0.82	0.17	0.09	1.85
55	Cuparene[ti]	1520	1518	1.38	0.09	0.14	0.04
56	δ-cadinene	1523	1524	0.12	–	0.07	0.13
57	(Z)-nerolidol	1530	1524	0.20	0.05	0.11	0.05
58	Elemol	1540	1540	0.11	0.06	0.07	0.08
59	Unidentified	1548	–	0.04	0.02	0.07	0.03
60	(E)-nerolidol	1551	1553	0.12	0.04	0.07	0.03
61	Caryophyllene alcohol	1557	1559	0.07	0.02	0.04	0.02
62	Unidentified	1566	–	0.03	0.11	0.07	0.07
63	Caryophyllene oxide	1570	1576	0.90	0.35	0.38	0.25
64	Unidentified	1582	–	0.06	0.04	0.05	0.05
65	Unidentified	1592	–	0.10	0.07	0.14	0.07
66	Unidentified	1598	–	0.10	0.03	0.05	0.07
67	Unidentified	1604	–	0.04	0.24	0.02	0.02
68	Cedrol[ti]	1608	1609	0.07	–	0.05	0.05
69	Unidentified	1614	–	0.38	0.24	0.22	0.27
70	A cadinol[ti]	1632	–	1.59	0.29	0.12	1.27
71	A cadinol[ti]	1639	–	0.26	0.12	0.15	0.25
72	Unidentified	1649	–	–	0.05	0.02	0.04
73	Unidentified	1651	–	–	0.05	0.05	0.12
74	β-Bisabolol	1666	1666	0.20	0.09	0.17	0.14
75	Unidentified	1687	–	0.06	0.02	0.02	0.04
76	Unidentified	1692	–	0.06	0.11	0.03	0.94
77	Unidentified	1712	–	0.02	0.07	0.06	0.02
78	Unidentified	1725	–	–	–	0.04	0.01
79	Unidentified	1778	–	0.09	–	t	0.16
80	Unidentified	1787	–	0.01	–	t	0.01
81	Unidentified	1823	–	–	–	0.04	–
82	Unidentified	1832	–	t	t	t	t
83	Unidentified	1858	–	t	t	t	0.05
84	Unidentified	1872	–	t	t	t	t
85	Unidentified	1876	–	t	t	t	t
86	Unidentified	1886	–	t	t	t	0.05
87	Unidentified	1900	–	t	t	t	0.03

Exp = experimental; Ref = reference; t = trace (<0.01%);
*correct isomer not given; ti = tentative identification; 1 = Panniyur-1; 2 = Panniyur-2;
3 = Panniyur-3; 4 = Panniyur-5.
(*Source*: Gopalakrishnan *et al.* 1993)

citronellal, nerol geraniol, isopinocamphone, methyl citronillate, methyl geranate, α-terpenyl acetate, terpenolene epoxide and *trans*-limonene epoxide.

2. *Sesquiterpene hydrocarbons and oxygenated compounds.* About 25 sesquiterpene hydrocarbons are present in pepper oil, the most important one being β-caryophyllene (Fig. 7.8). The others are α-*cis*-bergamontene, α-*trans*-bergamontene,

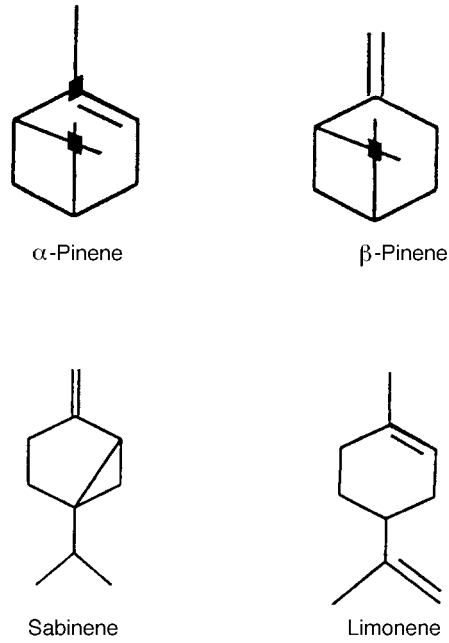


Fig. 7.7 Chemical structures of α-pinene, β-pinene, sabinene and limonene.

β-bisabolene, δ-cadinene, γ-cadinene, calamenene, α-copaene, α-cubebene, β-cubebene, ar-curcumene, β-elemene, δ-elemene, β-farnasene, α-guaiene, α-humulene, γ-humulene, isocaryophyllene, γ-muurolene, α-santalene, α-selinene, β-selinene, ledene, sesquisabenene and zingiberene. The oxygenated sesquiterpenes identified in pepper essential oil are: 5,10(15) cadinen-4-ol, caryophylla-3-(12), 7(15)-dien-4-β-ol, caryophylla-2,7 (15)-dien-4-β-ol, caryophylla-2-7 (15) dien-4-, β-ol, caryophyllene alcohol, caryophyllene ketone, caryophyllene oxide, epoxy-dihydrocaryophellene, *cis*-nerolidol, 4,10,10-trimethyl-7-methylene bicyclo-(2.0) decane-4-carboxaldehyde, γ-eudesmol, elemol, cubebol, α-bisabolol, β-bisabolol, viriideflorol, cubenol and epi-cubenol.

3 *Miscellaneous compounds*. In addition to the above groups of compounds many others were also identified in black pepper oil. They are: eugenol, methyl eugenol, benzaldehyde, *trans*-anethole, myristicin, safrole, piperonal, m-methylacetophenone, ρ-methylacetophenone, n-butyrophenone, methylheptanone, pinol, methyl heptanote,

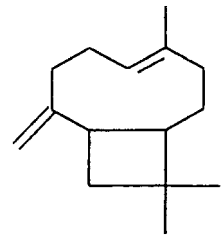


Fig. 7.8 Chemical structure of β-caryophyllene.

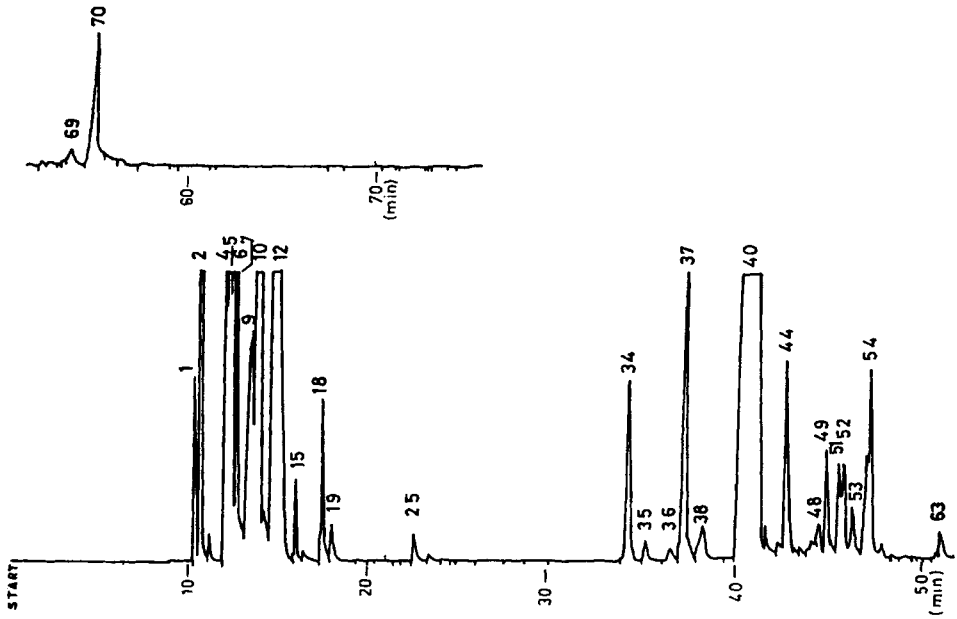


Fig. 7.9 Gas chromatogram of pepper oil (Panniyyur 5), 50 M methyl silicone column (Source: Gopalakrishnan *et al.* 1993).

methyloctanoate, 2-undecanone, n-nonane, n-tridecane, and aromatic acids such as benzoic acid, phenyl acetic acid, cinnamic acid, piperonic acid, butyric acid, 3-methyl butyric acid, haxanoic acid and 2-methyl pentanoic acid.

Compositional variations were reported among cultivars. Lewis *et al.* (1969) studied 17 cultivars from Kerala and found that the oil content ranged from 2.4–3.8%. In the oils, monoterpene hydrocarbons ranged from 69.4–84%, sesquiterpene hydrocarbons 15–27.6% and the rest were oxygenated constituents. The dominating monoterpene hydrocarbons were α-pinene (5.9–12.8%), β-pinene (10.6–35.5%) and limonene (22–31.1%). β-caryophyllene (10.3–22.4%) constituted the major sesquiterpene hydrocarbon. Significant differences in oil content and chemical constitution was reported by Russel and Else (1973) and Richard *et al.* (1971) who analysed the pepper samples from Lampong and Sarawak.

Gopalakrishnan *et al.* (1993) studied four genotypes (released varieties) of pepper using GC+MS employing methyl silicone capillary column. A model GC profile is given in Fig. 7.9. The oil of these cultivars possessed α-pinene in the range of 5.07–6.18%, β-pinene 9.16–11.08%, sabinene 8.50–17.16%, limonene 21.06–22.71% and β-caryophyllene 21.52–27.70%.

7.7.3 Phenolic components of pepper

The phenolic components of black pepper are a mixture of the glycosides of phenolic acids and flavonol glycosides. Parmar *et al.* (1997) listed the following flavonols from pepper: quercetin, isoquercetin, isorhamnetin 3-β-D-rutinoside, kaempferol 3-arabinoside, kaempferol-3-o-β-galactoside, quercetin-3-o-β-D rutinoside. Pepper also contains sitosterol. Grewe *et al.* (1970) found several lignans. One of them was identified as cubebin, which had been isolated earlier from *P. cubaba.*

7.8 Quality issues

7.8.1 Sensory quality evaluation of oil

The odour of pepper oil is described as fresh, dry-woody, warm-spicy and similar to that of crushed black peppercorn. Pangburn *et al.* (1970) made a sensory evaluation study of Malabar pepper oil after column chromatographic fractionation and mixtures of fractions at varying proportions. The early fractions were pepper like and floral and the late fractions pepper like, fresh and woody and the middle fractions falling in between. Govindarajan (1977) made extensive studies on odour analysis of pepper varieties. Using similar techniques Gopalakrishnan *et al.* (1993) described odour evaluation of four pepper varieties which they have examined by GC-MS. They depicted the odour profile on a four-point category scale and subjected the oils to ranking tests. The mean of the scores for each odour characteristic was plotted on radiating lines representing odour characteristic in sequential odour from left to right. The desirable odours are in the upper quadrants, the undesirable ones in the lower quadrants. The aromagram developed by these authors is given in Fig. 7.10.

7.8.2 Flavour and off flavour compounds

Jagella and Grosch (1999a, 1999b, 1999c) carried out some studies on the flavour and off flavour contributing components of black pepper. Their dilution and concentration experiments as well as enantio-selective analysis of optically active monoterpenes indicated that (+)-linalool, (+)-alpha-phellandrene, (-)-limonene, myrcene, (-)-alpha pinene, 3-methylbutanol and methyl propanol as the most potent odourants of black

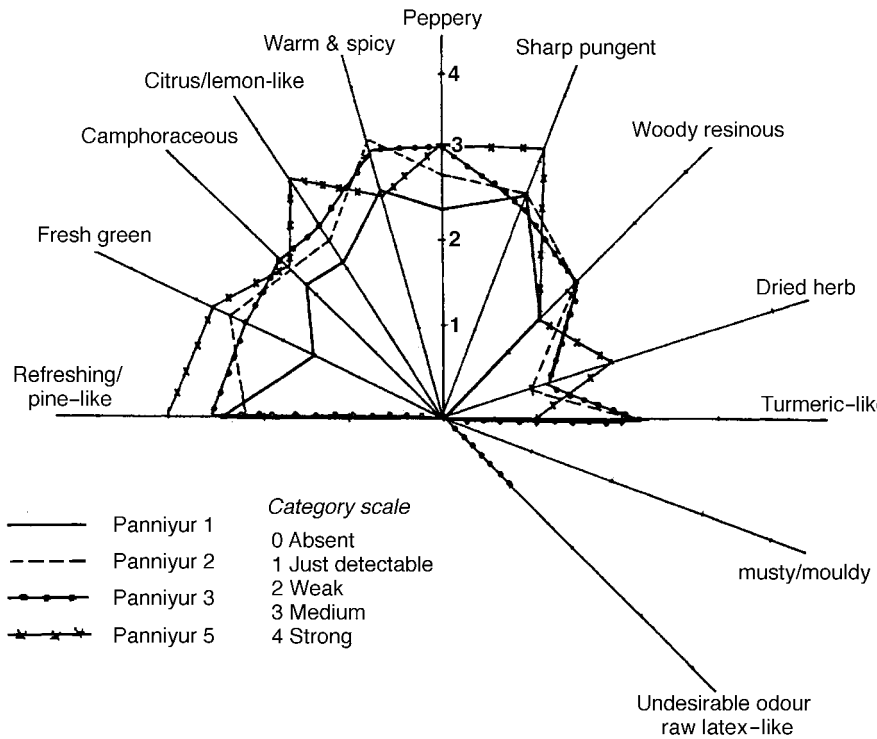


Fig. 7.10 Odour profilograms of pepper cultivars (Source: Gopalakrishnan *et al.* 1993).

pepper. The mouldy, musty off-flavour of Malaysian pepper is shown to be due to 2-isopropyl-3-methoxypyrazine and 2,3-diethyl-5-methylpyrazine. A storage experiment revealed that for ground pepper losses of α-pinene, limonene and 3-methylbutanal were mainly responsible for deficits in pepper-like, citrus-like, tepene-like and methyl notes after 30 days storage at room temperature. Jagella and Grosch (1999c) developed an aroma model for pepper based on the quantification of 19 odorants and calculation of their odour activity values. Omission tests conducted by them indicated that limonene, linalool, α-pinene, 1,8-cieole, piperonal, butyric acid, 3-methylbutyric acid, methyl propanal, 2- and 3-methylbutanal as key odorants of white pepper. The faecal off-flavour was caused by skatole and was enhanced by the presence of ρ-cresol.

7.8.3 Adulteration

The common adulterants used in whole or ground pepper are low quality pepper and various foreign matter. Synthetic compounds and cheap volatile sources are used to adulterate pepper essential oil (Sen and Roy 1974). Pepper berries are adulterated with stems, chaff or similar organic extraneous matter.

7.9 Industrial processing

The importance of value addition in pepper has been recognized by traders, and technologies have been developed for processing of pepper into a variety of products for consumer use. The pepper produced and dried at the farm level is subjected to grading and further processing. The dried pepper is sent through a variety of processing equipments such as mechanical sifter for removal of pinheads, vegetable seeds, sand dust and similar contaminants; and then to winnowing and destoning for removal of dust, stalks, light foreign matter and stones. These operations are now carried out in multiple-sieve cum air-classifier type of machine and gravity separators. From gravity separators pepper is conveyed to mechanical washers fitted with brushes for removal of dust, dirt, mould growth, etc., and for imparting a good shine to the product. The cleaned and washed pepper is then centrifuged to remove water, dried in a drier (usually diesel-fired or electric but with indirect heating). Finally the dried pepper is sent through spirals for final cleaning followed by sterilization either by steam or gamma radiation and packed in suitable polythene-lined packaging.

7.9.1 White pepper

White pepper is an important product mainly used in food items where the dark particles are undesirable, such as salad dressings, soups, mayonnaise, light coloured sauces, etc. White pepper is prepared from fully ripe fruits by removing the outer pericarp before drying. White pepper is produced conventionally from ripe berries by the water steeping and retting technique. Though other techniques were tested, they never found acceptance with consumers. In the water steeping and retting technique ripe berries and berries that are about to ripen are harvested, threshed and heaped in tanks through which water is allowed to run for 7–10 days. In Indonesia (which is the largest producer and exporter of white pepper) the pepper berries are tied in gunny bags and immersed in running water in streams or rivulets. During the process of water steeping the outer skin (pericarp) gets rotten and can be removed easily by rubbing and the deskinned fruits (seeds) are further

washed in clean water and sun dried. Often the deskinned fruits (seeds) are kept immersed in bleaching powder solution for a day or two to give better colour to the product. The yield of white pepper will be around one quarter instead of one third recovery of dry black pepper.

7.9.2 Ground pepper

In Western countries the most common form of black pepper available to the consumer is ground pepper. Ground pepper is produced by grinding dried, cleaned and sterilized white or black pepper in a hammer mill having copper tipped hammers. The ground pepper is then sieved in sieves of required mesh size and packed in airtight containers. The following points have to be kept in mind in the production of ground pepper (Ravindran *et al*. 2000a)

- Moisture level should be kept to a minimum as high moisture will affect the storage life.
- Volatile oil content should not be affected during the grinding process.
- Particle size should be optimum so as to ensure free flow for the duration of its shelf-life.
- Packaging should be airtight and safe.
- Microbiological cleanliness (freedom from moulds and bacteria) should be ensured.

A more recent development is cyrogrinding. In this new technique the grinding is done at low temperature to reduce the oil loss. This is done by injecting liquid nitrogen into the grinding zone and the temperature is adjusted suitably through the control of LN_2 flow rate. The cryogrind spice dispense more uniformly in spice formulations and the volatile oil and flavour loss are minimized.

7.9.3 Pepper oil

As already mentioned the aroma and flavour of black pepper is due to the essential oil content and this oil can be recovered by hydrodistillation or steam distillation. The essential oil contains monoterpenes, sesquiterpenes and their oxygenated derivatives having boiling points in the range of 80–200ºC. Industrial production of pepper essential oil is by steam distillation, by passing steam through pepper powder contained in a distillation chamber. The volatile oil that comes out along with the steam is collected in the condenser and later recovered, dried and stored in airtight containers.

7.9.4 Oleoresin

Oleoresin is commonly marketed as spice drops and contains the total pungency and flavour constituents of pepper. Oleoresin is produced by solvent extraction of pepper powder using a suitable organic solvent such as acetone, ethanol, ethyl acetate or ethylene dichloride. Either a one-stage or a two-stage process is employed for this. In the first case the oil is recovered along with the resins by solvent extraction. In the second process the oil is recovered by steam distillation followed by solvent extraction for recovering the oleoresin. Later the oleoresin and oil are blended to meet the required specifications. The organic solvent should be recovered completely from the oleoresin and the ISO as well as the importing countries have fixed maximum permissible limits for the approved solvents. The whole extraction process of oleoresin is usually done in batch extractors.

7.9.5 Supercritical fluid extraction (SFE)

SFE is the most versatile separation technology now being employed. It has a high extraction selectivity from a mixture of components because of the pressure-temperature dependent solubility in the solvents. The pepper raw material is loaded into the extractor and brought into contact with the supercritical solvent at relatively high pressures of 80–350 bar, at temperatures of 35–70ºC. The solute mixes into the supercritical solvent and both are passed through a pressure-reducing valve. The pressure on the separator side is about 40–60 bar, while the temperature is lower due to sudden expansion of the supercritical solvent. These conditions lower the solubility of the pepper raw materials in the solvent. When the material starts to separate, the gas is again compressed back to extract the material. Solvent recycling is achieved by means of a compressor (Anon. 1997).

Supercritical CO_2 is an ideal solvent for extraction of pepper, because it is cheap, abundant, inert, non-toxic, non-corrosive, non-inflammable and does not pollute the environment. Separation can be carried out at low temperature, residual solvent content can be reduced to near zero, solubility variation of active constituents can be easily manipulated, fractions can be extracted easily, the process consumes little energy, transfer rates are high and there are no fire hazards. Pepper extraction has been very successful with about 98% extraction of piperine and 81% of essential oil. The quality of the product is high compared to conventional extraction process.

The extracted oleoresin is also used for the separation of piperine by centrifuging the oleoresin in a basket centrifuge. From the oleoresin numerous secondary products have been developed having specified flavour strength and other properties. Such products include seasonings, emulsions, solubilised spices, dry soluble spices, encapsulated spices, heat resistant spices, fat based spices, etc.

7.9.6 Microencapsulated pepper

Microencapsulation is a recent development in which the flavour material is entrapped in a solid matrix, but releases the flavour when the product comes into contact with water or on heating. Methods such as spray drying, co-acervation, polymerization, etc., are made use of in microencapsulation. The process involves homogenization of the oil/water mixture in presence of the wall material followed by spray drying under controlled conditions. The wall materials used commonly include vegetable gums, starches, dextrins, proteins, cellulose esters, etc. A process known as CR-100, has been developed for microencapsulation which overcomes the limitations of the spray during process (Narayanan *et al.* 2000).

7.10 Pepper products

Much effort have been made in value addition of pepper and a variety of products have been developed. Such value added products are classified as 1) green pepper based products, 2) black pepper and white pepper based products, 3) pepper byproducts (Ravindran *et al*. 2000a).

(1) Green pepper based products:
- Canned green pepper in brine
- Bottled green pepper in brine

- Bulk packaged green pepper in brine
- Cured green pepper (without any covering tissue)
- Frozen green pepper
- Freeze dried green pepper
- Semidried or dehydrated green pepper
- Green pepper pickle in oil/vinegar/brine
- Green pepper-mixed pickle in oil/vinegar/brine
- Green pepper flavoured products
- Green pepper paste

(2) Black and white pepper based products:
- Black pepper powder
- White pepper powder
- White pepper whole
- Pepper oleoresin
- Pepper oil
- Microencapsulated pepper
- Other pepper products (such as soluble pepper, pepper paste)
- Byproducts from pepper waste

(3) Pepper based products:
- Many products, in which pepper is a major ingredient, have been developed such as lemon pepper, garlic pepper, sauces and marinades that have pepper as the main component.
- Spice mixtures and blends – curry powders and spice blends for various culinary uses.
- Pepper flavoured products such as pepper mayonnaise, pepper cookies, pepper keropak, pepper tofu, etc.
- Products using pepper extracts – pepper candies, pepper perfume, etc.

7.11 Functional properties

The nutritional composition of black pepper is shown in Table 7.13. Black pepper is an essential ingredient in the Indian systems of medicines – *Ayurveda*, *Sidha* and *Unani*, and is used as a curative agent for many maladies. Pharmacological studies have substantiated many of these traditional uses. (For a detailed discussion, see Vijayan and Thampuran, 2000.) Pepper has been seen as demonstrating a number of functional properties, including:

- analgesic and antipyretic properties
- antioxidant effects
- antimicrobial properties.

Piperine, the active ingredient in pepper, exerts substantial analgesic and antipyretic effects. Lee *et al.* (1984) found that piperine reduces inflammation in carragenin induced tests at an oral dose 50 mg/kg body weight. The anti-inflammatory effect was substantiated by Kapoor *et al.* (1993). Piperine and its homologues get absorbed through skin, and hence are capable of acting on the subcutaneous tissues as well as on nerves and blood vessels. The effect of pepper on the nervous system and on sexual organs (priapism) indicates anticonvulsive and vasodilatoral properties. Pepper also has an effect on lactation by increasing milk production. Pepper oil warms the skin and brings blood to the surface, stimulating circulation.

Table 7.13 Nutritional composition of black pepper per 100 grams

Composition	USDA Handbook 8–2[1]	ASTA[2]
Water (grams)	10.510	8.000
Food energy (Kcal)	255.000	4000.000
Protein (grams)	10.950	10.000
Fat (grams)	3.26[3]	10.200
Carbohydrates (grams)	64.810	66.500
Ash (grams)	4.330	4.600
Calcium (grams)	0.437	0.400
Phosphorous (mg)	173.000	160.000
Sodium (mg)	44.000	10.000
Potassium (mg)	1,259.000	1,200.000
Iron (mg)	28.860	17.000
Thiamine (mg)	0.109	0.070
Riboflavin (mg)	0.240	0.210
Niacin (mg)	1.142	0.800
Ascorbic acid (mg)	–	ND[4]
Vitamin A activity (RE)	19.000	19.000

[1] Composition of Foods: Spices and Herbs. USDA Agricultural Handbook 8–2, Jan 1977.
[2] The Nutritional Composition of Spices, ASTA Research Committee, Feb 1977.
[3] Piperine subtracted from lipid value.
[4] ND = Not detected.

In *Ayurveda*, pepper is used in the treatment of epileptic fits and to bring about sleep. Piperine exhibited protection against penetrazole induced seizure and also against electroshock seizure (Won *et al.* 1979). Piperine also possesses strong potentiating effect on hexobarbital induced hypnosis in mice. A compound of great interest extracted from pepper is 1-(3-benzodioxol-5yl)-1-oxo-2-propenyl-piperidide, known as antiepilepsirine, which was shown to have strong antiepileptic properties. This is used in Chinese hospitals for the treatment of epilepsy (Ebenhoech and Spadaro 1992).

Both pepper and piperine exert liver protective action. Kaul and Kapil (1993) found that piperine reduces *in vitro* and *in vivo* lipid peroxidation and prevents depletion of GSH (Gastricsulfhydryls) and total thiols. This is a very significant property, as lipid peroxidation causes free radical production that causes tissue damage. Pepper has antioxidant activity which is attributed to the tocopherol and polyphenol contents in pepper. Supercritical carbon dioxide extracts of ground black pepper have been found superior in reducing lipid oxidation of cooked ground pork (Tipsrisukond *et al*. 1998). The antioxidative activity of black pepper can, at least partially, be ascribed to the presence of glycosides of the flavonoids kaempherol, rhamnetin and quercetin (Vösgen and Herrmann 1980), as well as to the phenolic amides. Nakatani *et al.* (1986) established that all the five phenolic amides present in pepper possess very good antioxidant property, which is even superior to that of the synthetic antioxidants like butylated hydroxy toluene and butylated hydroxy anisole.

Addition of pepper to foods increases their keeping quality and prevents their spoilage, due to the antimicrobial properties of pepper. The essential oil of pepper is found to be inhibitory to *Vibrio cholerae*, *Staphylococcus albus, Clostridium diphthereae, Shigella dysenteriae*, *Streptomyces faecalis*, *Bacillus* spp., *Pseudomanas* spp., etc. Pepper oil stopped the growth and aflatoxin production by *Aspergillus parasitics* at a concentration of 0.2–1%. Pepper leaf oil also exhibits antifungal activity.

Pepper as well as piperine increases the bioavailability of medicaments including ampicillin and synthetic drugs as well as uptake of amino acids from food (Johri *et al.* 1992). Piperine seems to interact with the intestinal cells so as to increase the cell permeability. Piperidine is noted as a CNS-depressant, insectifuge, spinoconvulsant and urate solvent. The amides present in pepper have been shown to have insecticidal properties. Vijayan and Thampuran (2000) give a detailed account of the pharmacological and toxicological properties of pepper and piperine.

There is a current movement towards natural organic health supplements and medicines as substitutes for synthesized chemical drugs. The health promoting properties of pepper (as well as other spices) are being increasingly documented. Continued research is needed in this field to confirm their reported attributes.

7.12 Use of pepper in food

A spice is used in cooking for the following purposes:

- flavouring
- masking/deodorizing
- pungency
- colorant.

The spice interacts with the taste buds as well as other components of food leading to complex effects. A spice thus induces both direct and indirect (complex) effects as shown in Table 7.14 (Hirasa and Takemasa 1998).

Black pepper is the most widely used spice and occupies a proud place in the cusines of both West and East, with both vegetarian and non-vegetarian cooking. Black pepper contributes towards flavour, taste, antifungal, antibacterial and antioxidant properties, and hence pepper is a multifunctional spice, the predominating ones being taste and flavour.

Hirasa and Takemasa (1998) discuss the patterning theory of spice use and conclude that pepper is suitable for dishes of meat, seafood, milk, egg, grains, vegetables, fruit, bean and seeds and beverages. Pepper plays an important role in the cuisines of China, South East Asia, India, US, UK, Greece, Italy and France. In the case of cooking technique pepper is suitable for simmered, fried, steamed, deep-fried, food dressed with sauce, pickled and fresh food; but less suitable for baked food. The suitability pattern of pepper is represented in Fig. 7.11 (Hirasa and Takemasa 1998). There is almost no difference in suitability of pepper between Eastern and Western or continental cooking though it shows a very high suitability for American cooking.

Table 7.14

Direct effect	Indirect (complex) effect
Flavour	Increased appetite
Taste (pungency, bitterness, sweetness)	Masking effect
Colour	Improvement of texture and appearance
Antifungal effect	Preservation
Antibacterial effect	Preservation
Antioxidant effect	Preservation

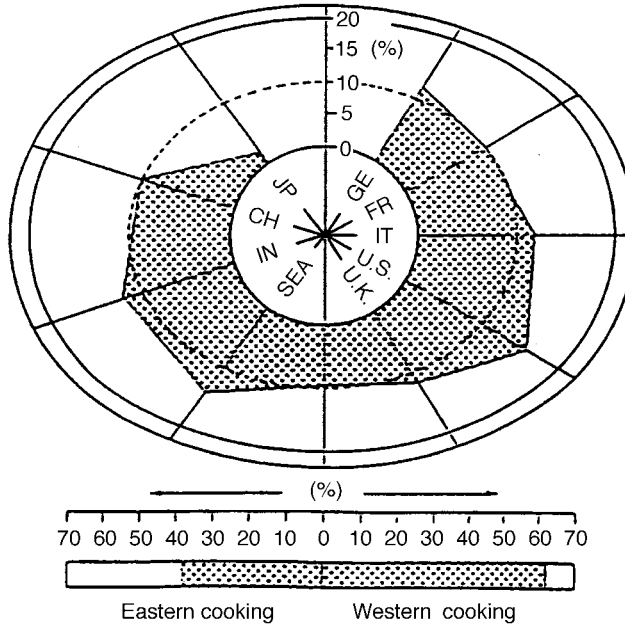


Fig. 7.11 Suitability pattern for pepper (*Source*: Hirasa and Takemasa 1998).

7.12.1 Use of pepper in curry powder

Pepper is an essential ingredient of most curry powders (masala mixes) used in cooking all over the world, but most extensively used in Indian as well as in South Asian cooking. There is an amazing variation of curry powders, to suit the hundreds of different 'curries' in the cuisines of these countries. Curry powders do play significant roles in the cuisines of other countries too. Curry powder is a mixture of coriander, cumin, turmeric, fenugreek, ginger, celery and black pepper and smaller amounts of chilli powder, cinnamon, nutmeg, clove, caraway and fennel, either with or without salt (Table 7.15). Many countries have their own specifications for curry powder. The federal specifications for curry powder (EE-S-631 J) are given in Table 7.16.

The famous oriental Five Spice Blend (FSB) used extensively in many meat and fish preparations has the following composition:

Ground cinnamon	25–50%
Ground anise (or star anise)	10–25%
Ground fennel	10–25%
Ground black pepper	10–25%
Ground cloves	10–25%

7.12.2 Soluble spice seasonings

Soluble seasonings are spice extracts mixed with a carrier like salt or dextrose. Oleoresin is used for the preparation of soluble spice. The most commonly used carrier is salt since the size of crystals provide good mixing action which disperses the oleoresin evenly (Tainter and Grenis 1993). But dextrose is preferred when a higher salt level is not desirable in the finished product. Soluble spices and seasonings are more often used in the processed foods industry, mainly because of the convenience involved in its use compared to the extracted

Table 7.15 Typical curry powder formulation indicating the range of spices (*Source*: Tainter and Grenis 1993)

Ingredient	Typical range (%)
Ground coriander	10–50
Ground cumin	5–20
Ground turmeric	10–35
Ground fenugreek	5–20
Ground ginger	5–20
Ground celery	0–15
Ground black pepper	0–10
Ground red pepper	0–10
Ground cinnamon	0–5
Ground nutmeg	0–5
Ground cloves	0–5
Ground caraway	0–5
Ground fennel	0–5
Ground cardamom	0–5
Salt	0–10

oleoresin or oil. For example pepper oleoresin is a thick, green, viscous liquid, difficult to mix uniformly and is not easy to pour, and is very difficult to measure when only small quantities are required. On the other hand, soluble black pepper is a free flowing powder, easy to weigh, and to add to a batch of products uniformly and accurately. Finally, waste is minimized compared to the oleoresin. When oleoresin is added it can lead to lump formation preventing uniform mixing, while the soluble salt ensures absolute uniformity while mixing. A typical soluble black pepper formulation consists of the following composition:

Oleoresin of black pepper	2–5%
Anticaking agent	up to 2%
Salt or dextrose	to make 100%

Pepper is an important ingredient in many flavouring and seasoning formulations – American, European as well as oriental. The contents of pepper in some of the well-known formularies are given in Table 7.17.

Consumers look for the organoleptic quality of foods rather than their nutritive value. Even the most nutritious food is not often accepted unless it is moderately spiced. It is an art to subtly blend flavouring and seasoning, to give distinctive tastes to the different dishes. All spices, particularly pepper, must be used with consummate skill. Even the

Table 7.16 Federal specifications (EE-S-631 J) for curry powder (*Source*: Tainter and Grenis 1993)

Ingredient	Limit (%)
Turmeric	37.0–39.0
Coriander	31.0–33.0
Fenugreek	9.0–11.0
Cinnamon	Not < than 7.0
Cumin	Not < than 5.0
Black pepper	Not < than 3.0
Ginger	Not < than 3.0
Cardamom	Not < than 2.0

Table 7.17 Pepper use in some of the flavouring and seasoning formularies (*Source*: Tainter and Grenis 1993)

Formulary	Content of pepper
Pickling mix	0–10%
Poultry seasoning	4.5–5.5%
Pumpkin pie sauce	0–5%
Oriental five spice blend	10–25%
Smoked sausage seasoning	6.57–7.03%
Italian sausage seasoning	2-6 oz/100 oz
Pork sausage	1–4 oz/100 oz
Bologna/weiner seasoning formulation	0.5–2% (oleoresin)
Roast beef rub formulation	0–5%
Pepperoni seasoning	1–4 oz/100 oz
Hot and spicy nut seasoning	0–5%

most insipid dishes can be improved by taking advantage of the pungent taste and spicy aroma of pepper to produce savoury dishes; that is why pepper is a universal favourite among the world's chefs. A list of oriental dishes where pepper is an essential component is given in Table 7.18.

Pepper is often used three times in the same dish before the food is eaten; first in the kitchen, as an ingredient in the dish; secondly, to correct or improve the overall seasoning during cooking; and thirdly at the dining table for the diners to add more spice and flavour to the prepared dishes.

Both white and black pepper are used. They are used whole, cracked, coarsely ground, medium ground or finely ground. Whole pepper corns are added as such to meat dishes, fish preparations, soups and pickles. Ground pepper is used in eggs, salads and gravies.

Table 7.18 Some important dishes flavoured with pepper

Beverages
1. Pepper tea
2. Pepper milk shake
3. Spicy water melon juice

Pickles/Chutneys
4. Pickled cherries
5. Pickled beef or pork
6. Pepper spike pickle
7. Coconut chutney
8. Fresh coriander chutney

Sweet preparations/confections
9. Quick banana pudding
10. Soji halwa

Snacks
11. Pepper biscuits
12. Vegetable crispies
13. Bonda
14. Pongal
15. Quick hamburger onion hash

Vegetable preparations
16. Vegetable curry
17. Vegetable korma
18. Masala del

Soups
19. Mixed vegetable soup
20. Cream of vegetable soup
21. Clear dhal soup

Legume/Pulse preparation to go with cereals
22. Radish sambar
23. Mulugutwanny (Rasam)

Meat dishes
24. Pepper steak
25. Black pepper pot roast
26. Pepper mutton balls
27. Black pepper fried chicken
28. Roghan josh
29. Korma curry

Other preparations
30. Amla preserve
31. French beans with coconut
32. Ground spice mixture

White pepper is popular in sauces and in preparations where pepper flavour is wanted but without the black specks.

Indian cooks use pepper and other spices in endless variations or combinations, and no two preparations have exactly the same combinations of spices. However, pepper is being used to a greater extent in American (US) cooking.

7.12.3 Masalas (spice mixes)

Though some foods such as fried potatoes, lady's finger (Okra), brinjal (egg plant), etc., use only two to three spices, most dishes are prepared with elaborate combinations of meticulously prepared and freshly ground spices referred to as masala. The masalas vary widely and each masala has a special purpose. Garam masala for example, is a blend of dried and powdered spices, to be used as such or in combination with other seasonings. Pepper has an important role in 'garam masala' along with cardamom, cloves and cinnamon. Premavalli *et al.* (2000) analysed various commercial brands of garam masala and 'puliyodara' mixes and found black pepper to be an important ingredient in all of them.

Pepper also is a must in freshly cut vegetable salads, such as cucumber, carrot, lettuce, radish, beetroot, onions, tomatoes, etc., in different combinations. Also, in the universally popular salad dressings, such as French dressing, pepper is a must. Further, as shown in the soup section of recipes (see Appendix), pepper is the only aromatic and piquant agent

Table 7.19 Sauce/seasoning and salad formulations containing pepper (*Source*: Farrell 1985)

Product	Ingredients
Sauce/seasoning	
Cucumber cream sauce	Lemon juice, cayenne pepper, white pepper, cream, mashed cucumbers
Cream sauce	Heavy cream, lemon juice, white pepper, onions, mustard
Sour cream sauce	Sour cream, lemon juice, white pepper, onions, egg, vinegar, dry mustard
Bearnaise sauce	Shallots, parsley, black pepper, terragon, chervil, vinegar, cayenne pepper, egg yolk, butter
Bechamel sauce	Chicken stock, butter, white pepper, onion
Diable sauce	Shallots, black pepper, white pepper, white wine, parsley, Worcestershire sauce
Horseradish sauce	Horseradish, white pepper
Poivrade game sauce	Onions, carrots, shallots, garlic, bay leaf thyme, vinegar, leaf stock, red wine, black pepper, parsley, olive oil, red currant jelly
Tourangelle sauce	Butter, onion, carrot, shallots, garlic, red wine, beef and chicken stocks, black pepper, parsley, bay leaf, thyme
Newburgh sauce	Mace, sherry wine, white pepper
Salad dressings	
Chicken	Capers, chives, curry powder blend, white pepper, fennel, marjoram, mustard, nutmeg, onion, paprika, poppy seed, rosemary, sesame seed, tarragon
Cabbage	Allspice, basil, white pepper, caraway seed, celery seed, dill, marjoram, mint, nutmeg, onion, chillies, poppy seed, paprika, rosemary, sesame, tarragon
Cucumber	Basil, capsicum, chervil, white pepper, dill, onion, paprika, terragon
Egg	Celery seed, chilli powder blend, white pepper, chives, chervil, dill, marjoram, mustard, onion, parsley, paprika, tarragon
Turkey	Capers, chives, curry powder blend, white pepper, marjoram, onion, paprika, poppy seed, rosemary, sesame seed, tarragon

Table 7.20 Commercial seasoning and instant gravy mixes containing pepper (*Source*: Farrell, 1985)

Name	% of pepper (white/black/oleoresin)
Frankfurter seasoning	
Formula A	5.72
Formula B	17.03
Formula C	3.73
Formula D	3.45 g (oleoresin) per 100 oz
Formula E	65.71 g/1000 oz (soluble spice in salt base)
Bologna seasoning	
Formula A	6.25
Formula B	0.37 (oleoresin)
Formula C	7.14 (soluble spice)
Fresh Pork Sausage seasoning	
Formula A	10.0
Formula B	7.5
Formula C	0.43 (oleoresin)
Italian seasoning	10.55
Italian sausage seasoning	10.0
Kielbase (Polish) seasoning	15.0
Smoked liver sausage seasoning	2.8 ground
Instant gravy mixes:	
Mushroom gravy seasoning and mix	0.46
Chicken gravy seasoning mix	0.33
Poultry gravy seasoning mix	0.026
Prawn gravy seasoning mix	0.46
French onion soup seasoning mix	0.004
Fish chowder seasoning mix	0.004
Chicken noodle soup seasoning mix	0.011
Shrimp seasoning mix	0.078
Fettucine Alfredo seasoning mix	1.0

in white sauces. Spikes of green pepper are used in a number of dishes in the households in Kerala, and Western Karnataka, India, where pepper is grown.

It is interesting to note that pepper goes into a variety of dishes, sweets and hot preserves and everyday dishes. It finds a place in exotic as well as bland preparations as in 'Roghan Josh' and in 'Dhal Soups'.

A list of recipes using pepper compiled by Dastur and Maya (1981) is given in the Appendix.

7.12.4 Condiments, sauces, seasonings

Condiments are prepared food compounds containing one or more spices, or spice extracts, which when added to a food, after it has been served, enhance the flavour of the food (Farrell 1985). Condiments can be either simple (e.g. celery salt, garlic salt, onion salt) or compound (chilli sauce, chutney, meat sauce, mint sauce, prepared mustard, etc.). Pepper forms an ingredient in many compound condiments. Pepper powder constitutes around 0.02% in prepared mustard formulations such as Dijon and Dusseldorf mustards, while in Swedish mustard, pepper is around 0.2%. Pepper is an ingredient in certain

Worcestershire sauce formulations. It forms about 5.2% of the famous Marinara and Parmesan seasoning mixes.

Sauces are hot or cold liquid or semi-liquid products (other than a condiment), which when added to a food as it is being served, adds to its acceptance by improving its appearance, aroma, flavour or texture. It may or may not include spices or spice extracts. Pepper is a component spice in sauces, salad dressings and seasoning formulations (Table 7.19) (Farrell 1985).

Seasonings are compounds containing one or more spice extracts which when added to a food, either during its manufacture or in its preparation, before it is served, enhance the natural flavour of the food and thereby increases its acceptance by the consumer (Farrell 1985). Black and white pepper is an ingredient in many famous seasoning formulations and instant gravy mixes (Table 7.20).

7.13 References

Note: For a comprehensive treatment of all aspects of black pepper, see P.N. RAVINDRAN (Ed.) (2000) *Black Pepper,* Harwood Academic Publishers, UK.

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Appendix: Recipes with pepper (Dastur and Maya 1981)

In the following pages are presented recipes of some well-known dishes where pepper appears as an important ingredient.

Beverages

Pepper tea

Ingredients	*Approximate measure*
1. Water for 4 cups	
2. Tea dust or leaves	3–4 teaspoons (depending upon strength desired)
3. Pepper corns (coarsely powdered)	10–12
4. Sugar	6–8 teaspoons
5. Milk as desired	

Method

1. Place tea leaves and coarsely powdered pepper in a pot
2. Pour boiling water (98°C is ideal) over the tea and pepper
3. Steep for 3 minutes and serve tea as usual with milk and sugar

Pepper milk shake

Ingredients	*Approximate measure*
1 Milk	$\frac{1}{2}$ litre
2. Sugar	10 teaspoons
3. Pepper corns (finely powdered)	8–10
4. Cashew nuts (finely cut and fried)	10–12

Method

1. Boil milk and sugar, stirring for about 20 minutes until it thickens a little
2. Chill
3. Garnish with pepper powder and cashew nuts before serving.

Note: This can also be served hot

Spicy water melon juice

Ingredients	*Approximate measure*
1. Water melon	1 medium sized
2. Pepper corn (powdered)	10

3.	Salt	a pinch
4.	Sugar	4 tablespoons (more if required)

Method
1. Cut water melon to fine pieces, remove the skin and seeds and pass through a blender.
2. Add salt and sugar and chill
3. Garnish with powdered pepper before serving.

Note: Tomato juice (fresh/canned/or pure beaten up) chilled can be garnished with powdered pepper and salt. This makes an excellent beverage in itself. It also serves as a base for several cocktails.

Pickles/chutneys

Pickled cherries

Ingredients		*Approximate measure*
1.	Cherries	1 kg
2.	Vinegar	$\frac{1}{2}$ litre
3.	Brown sugar	1 tablespoon
4.	Whole cloves	$\frac{1}{2}$ tablespoon
5.	Pepper corns	25–30
6.	Mace	2–3 pieces

Method
1. Put the cloves, pepper corns and sugar into the vinegar and bring to boil
2. Boil for 5 minutes and set aside to cool
3. Wash the cherries well and dry with a towel
4. Put the cherries in air-tight jars
5. Strain the vinegar and pour over the cherries, filling the jars to the brim
6. Seal well

Pickled pork or beef

Ingredients		*Approximate measure*
1.	Meat	500 gms
2.	Red chillies	6
3.	Cumin	$\frac{1}{2}$ teaspoon
4.	Mustard	$\frac{1}{2}$ teaspoon
5.	Turmeric	2.5 cm (1″)
6.	Pepper	25–30
7.	Ginger	2 inch piece
8.	Garlic	4–5 cloves
9.	Vinegar	$\frac{1}{2}-\frac{3}{4}$ litre

Method
1. Cut the meat into 2.5 cm (1″) cubes and wash in vinegar
2. Prick and rub well with salt and keep under a wt. for 24 hours
3. Wash the meat in vinegar and with the masala paste of ground red chillies, cumin, turmeric and mustard

4. Place the slices in a jar and sprinkle each layer with sliced ginger, garlic and pepper
5. Pour sufficient vinegar to cover the whole and shake the jar occasionally

Pepper spike pickle

Ingredients	*Approximate measure*
1. Green pepper spike	1 kg
2. Vinegar	600 ml
3. Garlic	1 pod (big)
4. Green chillies	10
5. Ginger	2 inch piece
6. Salt	$\frac{1}{2}$ cup
7. Turmeric	1 teaspoon
8. Oil	2 tablespoons

Method

1. Wash the pepper spikes, wipe and sprinkle over with salt and set aside for some time
2. Peel and slice garlic and ginger, slit green chillies
3. Heat oil. Add garlic, ginger and green chillies
4. Remove pan from fire and add turmeric, stir well
5. Add vinegar and salt. Bring to boil
6. Remove, cool and add prepared pepper spikes
7. Pack and store in airtight jars

Coconut chutney

Ingredients	*Approximate measure*
1. Coconut grated	5 tablespoons
2. Puffed Bengal gram dhal	2 tablespoons
3. Red chillies	1–2
4. Salt	1 teaspoon
5. Tamarind	a little ($\frac{1}{4}$ teaspoon)
6. Ginger	$\frac{1}{2}$ inch piece
7. Black gram dhal	1 teaspoon
8. Coriander leaves	1 bunch
9. Pepper	8–10
10. Mustard	$\frac{1}{4}$ teaspoon
11. Vegetable oil	1 teaspoon

Method

1. Grind together tamarind, salt, red chillies, puffed Bengal gram dhal, pepper, coriander leaves and ginger
2. Add coconut scrapings and grind again
3. Season with mustard and black gram dhal

Note: Red chillies can be replaced with green chillies.

Fresh coriander chutney

Ingredients	*Approximate measure*
1. Fresh lemon juice	3 tablespoons

2.	Water	3 tablespoons
3.	Fresh coriander stalks and leaves, thoroughly washed and coarsely chopped	10 medium-sized bundles
4.	Peeled finely chopped fresh coconut	1 big
5.	Finely chopped onion	1 medium
6.	Scraped, finely chopped fresh ginger root	$1\frac{1}{2}$ teaspoons
7.	Chopped red or green chillies	$1\frac{1}{2}$ teaspoons
8.	Sugar	1 teaspoon
9.	Salt	1 teaspoon
10.	Freshly ground black pepper	$\frac{1}{2}$ teaspoon

Method

1. Mix the lemon juice, water and the coriander and grind or blend at high speed for about 30 seconds
2. Add coconut, onion, ginger, chilli, sugar, salt and pepper and blend again
3. Add more sugar or salt if desired
4. Serve immediately. Can be kept in the refrigerator for 1 week

Note:

1. Mint or curry leaves can be substituted
2. If preferred traditional grinding stone can be used.

Sweet preparation in which pepper is used

Quick banana pudding

Ingredients		*Approximate measure*
1	Banana	4 large
2.	Coconut scrapings	1 cup
3.	Coarsely powdered pepper	$\frac{1}{4}$ teaspoon
4.	Jaggery	2 cubes

Methods

1. Peel bananas and slice
2. Add coconut scrapings and coarsely powdered jaggery
3. Add powdered cardamom and pepper and mix

Note:

1. Addition of thick curds to the above preparation will make it a dish to go with parotas or rotis
2. Jaggery can be substituted by sugar
3. If additional spiciness is preferred, $\frac{1}{4}$ teaspoon of dried ginger powder can also be added, and the quantity of sweetening agent increased slightly

Suji halwa

Ingredients		*Approximate measure*
1.	Wheat suji	1 cup
2.	Sugar	$1\frac{1}{4}$ cups

3.	Milk	1 cup
4.	Water	1 cup
5.	Raisins	10
6.	Cashew nuts	3
7.	Cardamom	2
8.	Pepper (dry powdered)	12
9.	Ginger (dry)	$\frac{1}{4}$ inch piece
10.	Fat	2 tablespoons

Method

1. Mix the sugar, milk and water and boil for a few minutes, and set aside
2. Mix wheat suji, fat and fry very slowly for 10 minutes
3. When suji becomes brown, pour the prepared syrup to the fried suji
4. Add raisins, cashew nuts and cook slowly until all the superfluous liquid is used up
5. Stir well with the ladle for 8–10 minutes
6. Then pour the halwa to a greased plate and cut into pieces
7. Sprinkle mixture of powdered cardamom, pepper and dried ginger

Snacks

Pepper biscuits

Ingredients		*Approximate measure*
1.	Wheat flour	3 cups
2.	Salt	$1\frac{1}{2}$ teaspoons
3.	Baking powder	1 teaspoon
4.	Fat	4 tablespoons
5.	Pepper	1 teaspoon
6.	Water	1 cup (slightly less)
7.	Sugar	$1\frac{1}{2}$ teaspoons

Method

1. Sieve wheat flour and baking powder
2. Add salt and freshly powdered pepper
3. Add fat and water and knead into a smooth dough
4. Roll and cut into biscuits and bake until light brown

Note:

1. These biscuits can also be deep fried
2. Addition of 1 teaspoon of powdered dry ginger and about 1 tablespoon of sugar and substitution of half the water with milk can also be done

Vegetable crispies (potato chips)

Ingredients		*Approximate measure*
1.	Potatoes	3 large sized
2.	Salt	to taste
3.	Pepper (ground)	$\frac{1}{2}$ teaspoon
4.	Oil for deep fat frying	$1\frac{1}{2}$ cups

Method

1. Wash and scrape potatoes
2. Slice into thin even circular slices
3. Keep in water to prevent browning and drain off water before frying
4. Deep fat fry a few slices at a time until crisp but not brown
5. Add salt and powdered pepper and shake

Note:

1. The other vegetables which can be used instead of potatoes are colocasia, yam, tapioca, sweet potatoes, plantatins, brinjals (large-sized) ash gourd skin
2. The vegetables can be cut into any desired shape such as finger chips, slivers, or thin slivers

Urd Bonda

Ingredients	*Approximate measure*
1. Black gram dhal	$\frac{1}{2}$ cup
2. Green chillies	2 (medium)
3. Ginger	$\frac{1}{2}$ inch piece
4. Pepper (whole)	30
5. Salt	to taste
6. Vegetable oil for frying	2 cups
7. Coconuts cut into small pieces	1 tablespoon
8. Coriander leaves	1 bunch (chopped)

Method

1. Soak black gram dhal for 4 hours
2. Drain water and grind into fine paste with salt ginger and green chillies
3. Add chopped coriander, cut coconut and whole black pepper to the ground dough
4. Divide into lime size portions and deep fat fry until brown

Pongal

Ingredients	*Approximate measure*
1. Rice	$1\frac{1}{2}$ cups
2. Green gram dhal	$\frac{3}{4}$ cup
3. Green chillies	4–5 chillies
4. Pepper corns	2–3 teaspoons
5. Ginger	1 inch piece
6. Fat	2 teaspoons
7. Cashew nut (optional)	20–22 nuts
8. Turmeric	$\frac{1}{2}$ teaspoon

Method

1. Chop green chillies and ginger
2. Heat fat and fry green chillies, ginger, pepper corns and turmeric
3. Fry the green gram dhal followed by rice, add water and salt and allow to cook
4. Garnish with fried nuts

Note:

1. Fresh chopped coriander leaves can be used for garnishing instead of cashew nuts

2. Green gram dhal can be substituted with other dhals such as (masur dhal) lentil and red gram dhal (tuar or arhar dhal)

Quick vegetable hamburger onion hash

Ingredients	*Approximate measure*
1. Minced onion	$\frac{1}{2}$ cup
2. Minced cooked carrot and turnip	$\frac{1}{2}$ cup
3. Butter or margarine	1 tablespoon
4. Finely chopped cooked potatoes	1–3 tablespoons
5. Salt	to taste
6. Ground black pepper	$\frac{1}{4}$ tablespoon
7. Garlic	2 cloves

Method:
1. Brown onion in butter or margarine
2. Add potatoes, salt, black pepper and ground garlic
3. Stir and cook 4 to 5 minutes
4. Serve hot with chapathi or bread

Note:
1. Addition of minced meat will make this a main dish
2. Left over vegetables can be used and spiced up with pepper and garlic, making a quick side dish for salt biscuits, rolls or buns

Vegetable preparations

Vegetable curry

Ingredients	*Approximate measure*
1. Vegetables	500 gms
2. Curd	4 tablespoons
3. Onion	4 medium
4. Garlic	8 flakes
5. Ginger	1 inch piece
6. Coriander	1 teaspoon
7. Pepper corns	10–12
8. Cumin seeds	$\frac{1}{2}$ teaspoon
9. Red chillies	3
10. Salt	to taste
11. Fat	1 tablespoon

Method
1. Clean and cut vegetables
2. Peel and slice garlic, ginger and onion
3. Soak garlic in a little water for 15 minutes
4. Pour this water over the vegetables and let it stand for half an hour
5. Heat fat, add sliced onion, vegetables soaked in garlic water and broken red chillies
6. In a thin muslin bag, tie the sliced ginger, pepper corns, cumin seeds and coriander seeds
7. Add in the muslin bag, salt and simmer until vegetables are tender

8. Remove the muslin bag with spices, squeezing out as much as possible of the juice into the vegetables
9. Add beaten curd and fry the vegetables until cooked

Note:
Cauliflower, potatoes, carrots, peas, knoll-khol, turnip and tomatoes can be used as vegetables, in convenient combinations

Vegetable khorma

Ingredients		*Approximate measure*
1.	Vegetables (potatoes, carrots, beans, peas, double beans – any choice)	500 gms
2.	Copra	1 tablespoon
3.	Onion	3 medium
4.	Ginger	1 inch piece
5.	Garlic	3–4 flakes
6.	Red chillies	4–5
7.	Curd	$\frac{3}{4}$ cup
8.	Coriander powder (dhania powder)	3 teaspoons
9.	Khuskhus (poppy seeds)	2 teaspoons
10.	Green chillies	2
11.	Cinnamon, cloves, pepper corns and cardamoms	1 teaspoon
12.	Fat	2 tablespoons

Method
1. Wash and cut vegetable
2. Soak in curd for half an hour
3. Grind together khuskhus, copra, garlic, ginger, coriander powder, red chillies (seed removed), green chillies and half the onion
4. Heat fat, fry remaining onion sliced
5. Add ground masala and vegetables. Fry for about 15 minutes over slow heat
6. Add remaining curd and tepid water and cook until vegetables are tender
7. Add cinnamon, cloves, pepper and cardamom roasted and powdered
8. Cook for 5 to 10 minutes more and serve hot

Masala dhal

Ingredients		*Approximate measure*	
1.	Red gram dhal	1 cup	Grind to a paste
2.	Red chillies	3	
3.	Garlic	6 cloves	
4.	Cumin	$\frac{1}{2}$ teaspoon	
5.	Pepper corn	10	
6.	Onions (sliced fine)	3	
7.	Garlic (chopped)	1 clove	
8.	Green chillies (slit)	2	
9.	Cumin (jeera)	1 teaspoon	

10.	Fat (or ghee)	1 teaspoon
11.	Salt	to taste

Method
1. Cook dhal with salt, until half done
2. Fry the onions in $\frac{3}{4}$ of fat, add masala paste and fry until brown
3. Mix this in dhal and cook until tender
4. Remove from fire and mash dhal
5. Using remaining fat season dhal with cumin, green chillies and chopped garlic

Note:
1. In the place of red gram dhal, other split dhals cab be used, such as masur dhal (lentil), green gram dhal, dried field beans dhal
2. Addition of tamarind and a little jaggery add to variety

Soups

Mixed vegetable soup

Ingredients		*Approximate measure*
1.	Onion	2–3 small sized
2.	Potatoes	2 medium sized
3.	Tomatoes	2 medium sized
4.	Carrots	2 small sized
5.	Turnip	1 small
6.	Celery (if available)	2–3 stalks
7.	Salt	to taste
8.	Pepper corns	10–12
9.	Milk	$\frac{1}{4}$ cup

Method
1. Chop all cleaned vegetables
2. Cook in water until tender (meat stock can be used instead of water, if available)
3. Pass through a sieve or colander and make a purée
4. Add to purée, milk and powdered pepper just before serving

Note:
To add more body to vegetable soup, $\frac{1}{4}$ cup of red gram dhal or green dhal may be added. The dhal should be half-cooked first, before adding vegetables

Cream of vegetable soup

To the vegetable soup prepared as shown in recipe above, white sauce is added before serving instead of milk and pepper

White sauce

Ingredients		*Approximate measure*
1.	Maida	3 tablespoons
2.	Fat	3 tablespoons
3.	Milk	300 ml

4.	Pepper (powdered)	12–14
5.	Salt	to taste

Method

1. Melt the fat in a pan over slow heat
2. Stir in maida with a wooden spoon, and fry
3. Add milk gradually, stirring all the time, taking care that no lumps are formed and until creamy texture is obtained
4. Add powdered pepper and salt
5. Add white sauce to vegetable purée, heat and serve

Clear dhal soup

Ingredients		*Approximate measure*
1.	Red gram dhal	$\frac{1}{4}$ cup
2.	Onions	1 small
3.	Ginger	$\frac{1}{2}$ inch piece
4.	Pepper	10–12
5.	Salt	to taste
6.	Milk	$\frac{1}{4}$ cup
7.	Turmeric	a pinch
8.	Water (or meat stock)	about 2–2$\frac{1}{2}$ cups

Method

1. Cook red gram dhal with chopped ginger, onion and turmeric until soft and set aside
2. Decant the top clear portion
3. Simmer the stock and add salt
4. Add milk, let simmer for about a minute and remove from heat
5. Add freshly ground pepper and serve hot

Note:

1. The solid dhal portion can be used for other preparations
2. Other pulses like green gram dhal and whole pulses like cowpea and horsegram can be substituted for red gram dhal
3. Tomatoes may be added to the dhal or whole dhals at the time of cooking

Legume/pulse preparations to go with cereals

Radish Sambar

Ingredients		*Approximate measure*
1.	Red gram dhal	$\frac{1}{2}$ cup
2.	Radish	3 medium
3.	Coriander seeds	2 teaspoons
4.	Pepper	1 teaspoon
5.	Red chillies	9
6.	Black gram	1 teaspoon
7.	Bengal gram dhal	1 teaspoon
8.	Grated coconut	1 teaspoon

9.	Tamarind	1 medium sized lime ball
10.	Salt	to taste
11.	Fenugreek	$\frac{1}{4}$ teaspoon
12.	Turmeric	$\frac{1}{4}$ teaspoon
13.	Mustard	$\frac{1}{4}$ teaspoon
14.	Vegetable oil	1 teaspoon

Method

1. Roast coriander seeds, pepper, black gram dhal, Bengal gram dhal, red chillies and fenugreek together
2. Roast separately grated coconut
3. Grind all these ingredients together (wet sambar masala)
4. Clean wash and cook red gram dhal with turmeric
5. When dhal is half cooked add cut radish pieces
6. When radish is cooked add tamarind juice, salt and boil
7. Then add the wet sambar masala and boil for about 10 minutes
8. Remove from the heat and season with mustard and curry leaves

Mulugutwanny type or Rasam

Ingredients		*Approximate measure*
1.	Red gram dhal	2 teaspoons
2.	Red chillies	4
3.	Tamarind	$\frac{1}{3}$ lime size ball
4.	Pepper	2 teaspoons
5.	Curry leaves	a few
6.	Cumin	$\frac{1}{2}$ teaspoon
7.	Coriander seeds	1 teaspoon
8.	Turmeric powder	a pinch
9.	Mustard	$\frac{1}{4}$ teaspoon
10.	Salt	to taste

Method

1. Wash and cook red gram dhal
2. Add turmeric powder
3. Roast cumin pepper, coriander seeds and red chillies and grind
4. Extract tamarind juice
5. Add tamarind juice, salt to cooked dhal
6. Lastly add powdered ingredients and let them simmer for about 5–8 minutes
7. Season with mustard and curry leaves, and remove from heat

Note:

1. This is served as soup also, before main meals
2. Tomatoes can be used for extra flavour, and the quantity of tamarind is reduced

Meat dishes

Pepper steak

Ingredients	*Approximate measure*
1. 4 thick slices of beef or (fillet) pork	
2. Onions (chopped fine)	2 medium
3. Whole pepper (crushed)	1 tablespoon
4. Mustard	$\frac{1}{2}$ teaspoon
5. Red wine (optional can be replaced by tomato juice)	1 cup
6. Fat	for frying about 3–4 tablespoons
7. Salt	to taste

Method

1. Using a mallet, beat the crushed pepper and salt on the four pieces of meat
2. Heat a little fat and brown the steaks on either side
3. Lightly fry the onion in a little fat separately and pour over the steaks.
4. Mix mustard in one cup red wine (or 1 cup tomato juice) and put in the same pan as the fried onions
5. Heat and pour over the steaks just before serving

Black pepper pot roast

Ingredients	*Approximate measure*
1. Bottom round of beef	2–2$\frac{1}{2}$ kg
2. Tomato paste	1 can (180 gms)
3. Bay leaf	1 small
4. Pepper corns	1$\frac{1}{2}$ teaspoons
5. Salt	1$\frac{1}{2}$ teaspoons
6. Minced onion	1 teaspoon
7. Ground black pepper	$\frac{1}{2}$ teaspoon
8. Small new potatoes	8 small
9. Carrots	6 medium

Method

1. Brown meat on all sides in heavy kettle
2. Add tomato paste, 1$\frac{1}{2}$ cups water, bay leaf, whole pepper, salt and minced onion
3. Cover and simmer for 3 hours, basting frequently
4. Add ground black pepper, potatoes and carrots, continue cooking for 30 minutes or until meat is tender

Pepper mutton balls

Ingredients	*Approximate measure*
1. Minced onion	1 teaspoon
2. Ground mutton	$\frac{1}{2}$ kg
3. Eggs	2
4. Bread cubes	1 cup
5. Salt	1 teaspoon
6. Ground black pepper	$\frac{1}{2}$ teaspoon
7. Ground ginger	$\frac{1}{2}$ teaspoon
8. Ground nutmeg	$\frac{1}{4}$ teaspoon

9.	Cooking oil	4–6 tablespoons

Method

1. Mix minced onion with 1 tsp water, let stand for 5 minutes to soften
2. Combine with remaining ingredients
3. Shape into 1-inch balls or into bite-sized balls and brown on all sides in hot oil
4. Serve with spaghetti or on toothpicks as cocktail balls

Black pepper fried chicken

Ingredients		*Approximate measure*
1.	Chicken	1 broiler
2.	Milk	1 cup
3.	Ground black pepper	$2\frac{1}{2}$ teaspoons
4.	Flour	$\frac{1}{2}$ cup
5.	Fat for deep frying	
6.	Milk (for gravy)	1 cup
7.	Flour	$\frac{1}{4}$ cup
8.	Salt	to taste

Method

1. Place chicken in a shallow dish. Combine 1 cup of milk, 1 teaspoon ground pepper and $\frac{1}{2}$ teaspoon of salt and pour over chicken
2. Cover and refrigerate for 2 hours
3. Combine $\frac{1}{2}$ cup of flour, remaining pepper and salt
4. Cut chicken and coat with flour mixture and refrigerate again for 1 hour
5. Cook chicken in deep fat for 15 to 20 minutes until brown and tender, and set aside
6. Make cream gravy the following way:
   a. Place $\frac{1}{4}$ cup of fat from deep frying in a saucepan
   b. Blend in $\frac{1}{4}$ cup of flour
   c. Add milk (left over milk plus more milk to make $2\frac{1}{2}$ cups) until medium thick Stir and cool
   d. Add salt and pepper (remaining $\frac{1}{2}$ teaspoon)
7. Add gravy to fried chicken pieces and serve with naan or chapathi

Roghan josh and curried lamb

Ingredients		*Approximate measure*
1.	Lamb (mutton)	1 kg
2.	Chilli powder	$\frac{1}{4}$ teaspoon
3.	Salt	1 teaspoon
4.	Yoghurt (curd)	12 tablespoons
5.	Ginger (scraped)	$2\frac{1}{2}$ teaspoons
6.	Ghee and butter	3 tablespoons
7.	Black pepper freshly ground	5 teaspoons
8.	Turmeric	2 teaspoons
9.	Coriander leaves (chopped)	$\frac{1}{2}$ teaspoon
10.	Garam masala	$1\frac{1}{2}$ tablespoons
11.	Ground spice mixture	$\frac{1}{2}$ teaspoon
12.	Water	12 tablespoons
13.	Nutmeg (freshly grated)	a pinch

Method

1. Place mutton pieces in a large shallow baking dish and sprinkle on it chilli powder and salt evenly
2. Mix together curd and crushed ginger and pour over the mutton pieces, coating all the sides evenly
3. Close the dish tightly and marinade at room temperature for 1 hour
4. Heat ghee in a heavy frying pan and stir in a liberal grinding of black pepper and turmeric and then mutton and its marinade
5. Bring to a boil over high heat turning and stirring constantly
6. Reduce heat, close pan tightly and let it simmer undisturbed for 1 hour
7. Remove cover, sprinkle chopped coriander and pour 6 tablespoons of water, cover again and let simmer for 15 minutes
8. Repeat this using 3 tablespoons of water and cook until tender
9. Remove from heat and sprinkle the top with garam masala and nutmeg

Korma curry

Ingredients		*Approximate measure*
1.	Mutton	$\frac{1}{2}$ kg
2.	Sour curd	2 cups
3.	Onion and garlic (finely chopped)	1 and 2 cloves respectively
4.	Ground pepper	$\frac{1}{2}$ teaspoon
5.	Ground ginger	$\frac{1}{2}$ teaspoon
6.	Ground cumin seed	$\frac{1}{2}$ teaspoon
7.	Ground chillies	$\frac{1}{2}$ teaspoon
8.	Ground mustard seed	$\frac{1}{2}$ teaspoon

Method

1. Fry finely chopped onion in 3 tablespoons of ghee or other fat
2. Add the mixture of meat and spices and cook slowly until the meat is tender
3. Salt and a squeeze of lemon juice is added before serving
4. If possible, cook this curry without water or stock
5. The curds will help to form a thick gravy if cooked slowly

Note:
Grind the spices and add to the curd and marinade the mutton pieces in the spicy curd for about 2 hours prior to cooking

Other preparations

Amla preserve

Ingredients		*Approximate measure*
1.	Amla	1 kg
2.	Sugar	800 gms
3.	Citric acid	1 teaspoon
4.	Nutmeg	a small piece
5.	Cloves	1 teaspoon
6.	Pepper corns	1 teaspoon
7.	Cardamom	1 teaspoon

Method

1. Powder all the spices coarsely except the pepper
2. Boil the amlas in water with a teaspoon of salt
3. Keep aside, covered with a lid, until cool
4. After cooling remove the seeds from the amlas and and keep the pieces aside
5. Dissolve the sugar in 700 ml of water, boil for about 10 minutes
6. Now add the amlas and citric acid to the syrup and boil for about 15 minutes until the syrup is thick
7. Add the powdered spices and the pepper, and remove from the heat after stirring well
8. Bottle when cool

French green beans fried with coconut

Ingredients	*Approximate measure*
1. Ghee or fat	3 tablespoons
2. Black mustard seeds	1 teaspoon
3. Black gram dhal	4 tablespoons
4. Finely chopped fresh ginger	1 teaspoon
5. Salt	1 teaspoon
6. Freshly ground black pepper	$\frac{1}{2}$ teaspoon
7. Green beans trimmed and cut across into paper thin rounds	$\frac{1}{2}$ kg
8. Chilli powder	1 teaspoon
9. Finely grated fresh coconut	3 tablespoons
10. Finely chopped fresh coriander	$1\frac{1}{2}$ tablespoons
11. Fresh lemon juice	$1\frac{1}{2}$ tablespoons

Method

1. Heat the ghee. Add the mustard seeds and black gram dhal and fry until the dhal browns lightly
2. Stir the onions, ginger, salt and chilli powder and drop in the green beans
3. Add the coconut and coriander, reduce the heat to low and cover the pan. Cook for about 10 minutes more, stirring occasionally until the beans are tender
4. Sprinkle with lemon juice, ground pepper corns for seasoning, and serve at once

Note:
In the place of French beans other vegetables which can be included are cluster beans, peas, tender cowpea, winged beans, cabbage, spinach and drumstick leaves

Ground spice mixture

Ingredients	*Approximate measure*
1. Three inch pieces cinnamon stick	5
2. Whole cardamom pods (preferably green cardamoms)	75 gm
3. Whole cloves	50 gm
4. Whole cumin seeds	50 gm
5. Whole coriander seeds	25 gm
6. Whole black pepper corns	75 gm

Method

1. Roast cinnamon, cardamom, cloves, cumin, coriander, pepper corns in one layer. Do not let the spices brown
2. Put the cardamom seeds, crushed cinnamon, cloves, cumin seeds, coriander seeds and pepper corns into a small pan or bowl and stir them together until they are well mixed
3. Grind the spices in convenient batches by pouring them into the jar of an electric mixer, blending at high speed for 2 to 3 minutes, until they become a smooth powder. As each batch of spice is ground, transfer it to a jar or bottle with a tightly fitting lid.
4. Garam masala may be stored at room temperature in an airtight container, and will retain its full flavour for 5 to 6 months

Note: In most homes, the traditional stone grinder is used.

8

Capsicum, chillies, paprika, bird's eye chilli

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8.1 Introduction: classification and use

Many different varieties of the genus Capsicum are widely grown for their fruits, which may be eaten fresh, cooked, as a dried powder, in a sauce, or processed into oleoresin.[1] There are three major products traded on the world market for use in food processing: paprika, oleoresin, and dried chilli (both whole and in powdered form). Some fresh fruits and some fermented mash is used for food processing, but these are relatively minor amounts and by necessity they are produced close to the processing facility.

The genus Capsicum belongs to the family Solanaceae. Within the genus Capsicum, five species are commonly recognized as domesticated: *Capsicum annuum*, *C. baccatum*, *C. chinense*, *C. frutescens*, and *C. pubescens*, while approximately 20 wild species have been documented. The genus Capsicum shares the distinction of being the first plants cultivated in the New World with beans (*Phaseolus* spp.), maize (*Zea mays* L.), and cucurbits (Cucurbitaceae).[2] They are one of the first spices used by humans anywhere in the world. Widespread geographic distribution of *C. annuum* and *C. frutescens* from the New World to other continents occurred in the sixteenth century via Spanish and Portuguese traders, whereas the other species are little distributed outside South America.[3] Most products used commercially for food processing are *C. annuum*.

The classification system for this genus is somewhat confusing in the literature. In Spain, the Castilian word 'pimiento' refers to any Capsicum species, but in the USA, 'pimiento' or 'pimento' refers only to thick-walled, heart-shaped, non-pungent fruits from the species *C. annuum*. The Hungarians call all *C. annuum* fruits 'paprika', but paprika is defined in the world market as a ground, red powder derived from dried fruits with the desirable colour and flavour qualities. The word 'chile' is the common name for any Capsicum species in Mexico, Central America and the Southwestern USA. In Asia, the spelling 'chilli' is more common and is always associated with highly pungent varieties of *C. annuum* and *C. frutescens*, while the non-pungent sweet bell peppers are referred to as 'Capsicums'. Pungent fruits of all cultivated Capsicum species as a collective class are called 'chillies' in the Food and Agriculture Organization (FAO) Yearbook.[4] Bird's eye chillies are grown primarily in East Africa, but they are merely

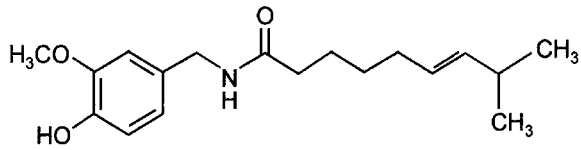
small-fruited, highly pungent forms of *C. annuum* or *C. frutescens*. In this review, the following definitions will be used:

- *Oleoresin* – a viscous liquid derived by polar solvent extraction from ground powder of any Capsicum species; there are three types of oleoresin: paprika (used for colour), red pepper (used for colour and pungency), and Capsicum (used for pungency).
- *Paprika* – a ground, bright red, usually non-pungent powder used primarily for its colour and flavour in processed foods; all paprika varieties are *C. annuum*; paprika fruits are used to produce paprika oleoresin.
- *Chilli* – any pungent variety of any Capsicum species, but primarily *C. annuum*; chilli varieties may be used to produce red pepper oleoresin or Capsicum oleoresin.
- *Pepper(s)* – generic term describing the fruits of any Capsicum species, both pungent and non-pungent.

Peppers are used as a colourant, flavourant, and/or as a source of pungency, depending on the processed product. Peppers can be used fresh, dried, fermented, or as an oleoresin extract. They can be used whole, chopped, coarsely ground, or finely ground, with or without seeds. Various types of processed products containing primarily peppers include pickled fruits, chilli sauce, chilli powder (also known as cayenne powder), crushed red pepper flakes (with or without seeds), fermented mash, paprika, and three types of oleoresin. Other processed products that contain a significant proportion of peppers include fresh and processed salsas, curry powders, barbecue seasonings, chili powder (a mixture of chilli powder, oregano, cumin, and garlic powder), and many other foods.[5]

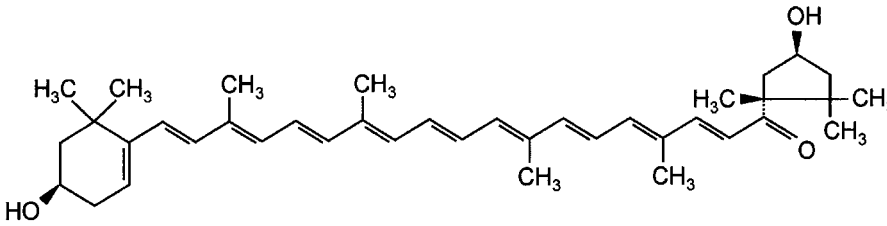
8.2 Chemical structure and stability

The main source of pungency in peppers is the chemical group of alkaloid compounds called capsaicinoids (CAPS), which are produced in the fruit. The atomic structure of CAPS is similar to piperine (the active component of white and black pepper, *Piper nigrum*) and zingerone (the active component of ginger, *Zingiber officinale*). Capsaicin ($C_{18}H_{27}NO_3$, trans-8-methyl-N-vanillyl-6-nonenamide), shown in Fig. 8.1, is the most abundant CAPS, followed by dihydrocapsaicin, with minor amounts of nordihydrocapsaicin, homocapsaicin, homodihydrocapsaicin, and others. Capsaicin is a white crystalline, fat-soluble compound formed from homovanillic acid that is insoluble in water, odourless, and tasteless.[3] Varieties of chilli differ widely in CAPS content. The amount of CAPS in a given variety can vary depending on the light intensity and temperature at which the plant is grown, the age of the fruit, and the position of the fruit on the plant. The first test developed to measure pungency was the Scoville test, first developed in 1912 by Wilbur Scoville.[6] It measures 'heat' as Scoville heat units (SHU) in a given dry weight of fruit tissue. Sweet peppers have 0 SHU, chillies with a slight bite may have 100 to 500 SHU, and the blistering habaneros have between 200,000 and 300,000. The red colour of mature pepper fruits is due to several related carotenoid pigments, including capsanthin (Fig. 8.2), capsorubin, cryptoxanthin, and zeaxanthin, which are present as fatty acid esters. The most important pigments are capsanthin and its isomer capsorubin, which make up 30–60% and 6–18%, respectively, of the total carotenoids in the fruit.[7] The intensity of the red colour is primarily a function of the amount of these two pigments; the Hungarian and Spanish varieties used for paprika have very high amounts of capsanthin and capsorubin compared to other varieties.[7]



Capsaicin

Fig. 8.1 Chemical structure of capsaicin.



Capsanthin

Fig. 8.2 Chemical structure of capsanthin.

CAPS in oleoresins are very stable compounds and generally do not break down, even during processing at high temperatures and during long storage periods. CAPS in dry products (fruits, powder, etc.) are not as stable as in oleoresins. The temperature at which the fruits are dried affects the CAPS content. For example, drying ripe fruits at 60ºC to a final moisture content of 8% decreases CAPS content approximately 10%.[8] If the fruits are held for extended periods of time at 60ºC after reaching 8% moisture content as much as 50% of the CAPS may be lost.[8] Once the fruits are dried, they typically lose 1–2% CAPS/month under cold (−16ºC) storage, and even more when stored under ambient conditions. Ground powder can lose as much as 5% CAPS/month depending on the fineness of the grind and the storage temperature.[8] The red colour of paprika and chilli powder, on the other hand, is not as stable as oleoresin and CAPS, and much work has been done to optimize the processing and storage conditions for dried chillies and paprika to maximize the colour intensity for the longest period of time.[9-11]

8.3 Production

Reliable production figures for paprika and chillies are difficult to obtain because the FAO Yearbook combines production figures for green bell peppers and chillies into one figure for peppers. In 1997, the FAO reported that there were 1.33 million hectares of peppers grown, with an average yield of 12.3 t ha^{-1}; total production was estimated at 16.4 million metric tons (MMT).[4] The major pepper producing nations in terms of area are India, China, Indonesia, Ethiopia and Mexico.

8.3.1 Paprika production

Paprika is produced commercially in Spain, Portugal, Central Europe, Southern Africa, and the US, but Hungary is by far the most famous paprika-producing country, with approximately 8,000 ha devoted to the crop.[4,12] Many food historians believe that Turks and Bulgarians of the Ottoman Empire brought peppers to Hungary in the sixteenth

century. Kalocsa and Szeged are the main centres of paprika production. Once the fruits are harvested, they are loosely stacked in long, narrow, cylindrical mesh bags made of red plastic and allowed to 'cure' for 3–4 weeks. Then the peppers are washed, dried, crushed and finally ground into powder. The mill master selects the proportion of seeds to be ground with the pepper pods, to produce the desired level of pungency and colour in the paprika. During grinding, the crushed peppers are heated to release the oil in the seeds, which interacts with the pigment in the fruits to produce the intense red colour. Colour has no effect on the pungency of the paprika. Bright red paprikas may be sweet or pungent. Generally, the poorer-quality, pale red and brownish-coloured paprikas are pungent. Heat causes the natural sugar content of the fruits to caramelize slightly, which affects the taste and aroma of the paprika. During the process, if the fruits are heated too much, they will scorch. If they are not heated enough, the moisture content will be too high, and both the flavour and colour will be affected. Optimum moisture content is 8%.[12] Only undamaged fruits less than a year old are used for the top grades of Hungarian paprika. Before non-pungent paprika varieties were available, the top grades of paprika were prepared by removing the dissepiment (ribs on the inside of the pericarp which are rich in CAPS) by special knives,[13] but this method is no longer used.[12]

8.3.2 Oleoresin production

Oleoresin is a viscous liquid or semi-solid material derived by extraction from finely-ground powder, which contains the aroma and flavour of its source. Three types of oleoresin are produced. High-pungency Capsicum oleoresin is produced in India, Africa and China near the production areas of low cost, very pungent chilli varieties. Medium-pungency red pepper oleoresin is produced in many regions. Non-pungent paprika oleoresin is produced in Spain, Ethiopia, Morocco, Israel, India, USA, Mexico and South Africa.[5] Oleoresin is extracted from finely ground chilli or paprika powder. A volatile non-aqueous solvent such as hexane, ether, or ethylene dichloride is added and allowed to thoroughly wet the material. The oleoresin enters into solution with the solvent, forming micella. After a period of time, the micella is removed, and the solvent replaced with fresh solvent to continue the extraction. The solvent is subsequently removed from the extract by evaporation at the lowest practical temperature to avoid loss of aromatic volatile compounds. This is done in two stages: the first stage removes approximately 95% in a standard film evaporator, and then the concentrated micella passes through a partial vacuum that removes the rest of the solvent and reduces the micella to oleoresin. The remaining solvent held in the mass of the extracted powder is recovered by very high vacuum. Typical yield of oleoresin depends on the solvent used and ranges from 11.5–16.5%.[5] The oleoresin pungency depends on the pungency of the original powder. Paprika oleoresin has little to no pungency, and is used for its colour and flavour properties, while Capsicum oleoresin can have CAPS levels up to 10%, and is used primarily as a source of high pungency.

8.3.3 Dry chilli production

Chilli peppers are typically produced on small farms, less than 1 ha in size, in areas where cheap labour is available for harvesting. The largest producer is India, with an estimated 894,000 ha devoted to the crop annually. India is the largest exporter of dried chilli in the world. The second-largest producer is China, which grows an estimated 216,000 ha annually and also exports sizeable quantities of dried chilli.[14] Fruits are typically allowed

to partially dry on the plant, then harvested and placed in well-ventilated areas receiving direct sunlight for drying. Sun drying can result in bleached fruits, especially if rainfall is received during the drying period, and the fruits may have extraneous matter adhering to them. In more advanced regions, the use of controlled drying improves the quality of the dried fruits. The best drying temperature is 60–70ºC; this gives maximum colour values and longest colour retention time. Higher temperatures tend to caramelize the sugars present in the fruits and give them a dark colour. The optimum moisture content is approximately 10%.[15-17]

8.4 Main uses in food processing

There are many uses of peppers in food processing, including as a food colourant, as a source of pungency in food, as a source of flavour, as a source of pain relief for pharmaceutical use, and as a repellent. In many cases two or more of these properties are included in the same product; for example, paprika may be a source of colour, pungency, and flavour.

8.4.1 Colour

People whose diets are largely colourless starches, such as rice or maize, use peppers to add colour to their bland, achromatic diets. Paprika, paprika oleoresin, red pepper oleoresin, and dried chilli may all serve as a source of red colour in various processed products, but the primary sources of red colour are paprika and paprika oleoresin. Paprika is used in many products where no pungency is desired, but the colour, flavour, and texture of a finely ground powder is desired. These include processed lunchmeats, sausages, cheeses and other dairy products, soups, sauces, and snacks such as potato chips. Paprika oleoresin is used as a colour and flavour additive in many products where the texture is important and small particles of paprika powder would be undesirable.[5]

8.4.2 Pungency

Red pepper oleoresin is used as a source of both colour and pungency in canned meats, sausages, smoked pork, sandwich spreads, soups, and in dispersed form in some drinks such as ginger ale. Capsicum oleoresin is used as a source of pungency in many products, especially chilli sauces with extremely high SHU ratings. Oleoresin has considerable advantages over dried chilli including more stable colour retention, easier to handle compared to the rather bulky dried chilli, and the ability to mix and dilute oleoresin with other substances to produce a range of colour and/or pungency values. Dried chilli is also used as a source of both colour and pungency, particularly in the production of crushed red peppers, chilli powder and chilli sauces.

8.4.3 Flavour

Paprika is valued for its flavour in many products in addition to its colour. Dried chilli is also valued for its contribution to flavour in chilli sauces and chilli powders. The flavouring principle is associated with volatile aromatic compounds and colour. As a general rule, when the colour of paprika or chilli powder fades, the flavour also disappears.

8.4.4 Pharmaceutical

Capsicum oleoresin is the primary form of peppers used for pharmaceutical purposes. Here the primary requirement is the CAPS level. Further refinement of the oleoresin may be performed to produce pure capsaicin. At least two types of pain relief products are currently being marketed, including creams containing 0.75% capsaicin (for example, Zostrix™), and plasters containing 3% oleoresin (for example, Vorwerk™). Several types of capsules containing chilli powder (cayenne powder) with a range of capsaicin levels are currently being marketed.

8.5 Functional properties and toxicity

Peppers are well-known for their health benefits. Herbalists have long promoted peppers for their health-enhancing effects. These include clearing the lungs and sinuses, protecting the stomach by increasing the flow of digestive juices, triggering the brain to release endorphins (natural painkillers), making your mouth water, which helps to neutralize cavity-causing acids, and helping protect the body against cancer through anti-oxidant activity.[3]

8.5.1 Toxicity

The acute toxicity of capsaicin has been measured in several animal species. In mice, the LD_{50} values for CAPS depended on the mode of administration, ranging from 0.56 (intravenous) to 512 (dermal) mg kg^{-1} body weight. Death was due to respiratory paralysis.[18] To reach the LD_{50} value for human oral administration, the average person would have to drink 1.5 quarts of Tabasco® sauce. The painfulness of the CAPS is a self-limiting factor in their role as a human food ingredient; you can only eat so much at one time. No death has ever been recorded due to CAPS-induced respiratory failure, and the investigators concluded that the acute toxicity of CAPS as a food additive in man was negligible.[18] The effect of sub-chronic toxic doses has been examined in rats. Adult rats exhibited no noticeable behavioural or physiological changes when given sub-chronic doses of crude chilli extract by stomach tube for 60 days. Food consumption was significantly higher but body weight was lower than the control group after 60 days.[19]

8.5.2 Functional benefits

CAPS stimulates sensory neurons in the skin and mouth cavity, creating a sensation of warmth that increases to severe pain (type C nociceptive fibre pain) with higher doses. The neurons produce the neuropeptide Substance P (SP), which delivers the message of pain. Repeated exposure of a neuron to capsaicin depletes SP, reducing or eliminating the pain sensation in many people.[20] Thus the use of CAPS in pain relief has two modes of action: the sensation of heat, which may help sore muscles and arthritic joints feel better, and the depletion of SP, which reduces the pain sensation in the exposed area. Peppers have been reported to contain an anticoagulant that helps prevent the blood clots that can cause heart attacks.[3] Foods containing CAPS increase the thermic effects of food (TEF). The TEF is the slight increase in the body's metabolic rate after consumption of a meal. A meal containing foods with CAPS can increase the body's TEF up to 25% for three hours.[3] The role of CAPS in triggering the brain to release endorphins (natural painkillers) is well-known. As more CAPS is consumed, the body releases more

endorphins, causing one to feel a mild euphoria – a natural high! Regular consumption has only a slight desensitizing effect.

The Hungarian scientist Albert Szent-Gyorgyi won the 1937 Nobel Prize for isolating ascorbic acid, better known as vitamin C, from peppers. Peppers are also high in vitamin A, vitamin E, and potassium, and low in sodium. One hundred grams of fresh red chilli pepper has 240 mg of vitamin C (five times higher than an orange), 11,000 IU of vitamin A, and 0.7 mg of vitamin E. Vitamin C is sensitive to heat and drying but vitamin A is very stable, and paprika and dried chilli both contain relatively high amounts of this important nutrient.[5]

8.6 Quality issues

The quality parameters of paprika, oleoresin, and dried chilli focus primarily on colour, pungency, and microbial and insect contamination, but vary depending on the product and the intended end use.

8.6.1 Paprika quality

Paprika always refers to a ground product prepared of highly coloured, mild or sweet red fruits. The main quality factors are colour and pungency. There are eight grades of Hungarian paprika (Table 8.1). The condition of the fruits at harvest, and to some extent the manner in which they are processed, determines which grade of paprika will be made from them. Fruits are graded at harvest for colour, pungency and aroma. The Grade 1 fruits are used to make the best grades of paprika (special, capsaicin-free, and delicatesse), while Grade 2 fruits are used to make lower grades of paprika (fine sweet, semi-sweet). Fruits from later harvests and those rejected from higher grades are used for rose, while spotted fruits not belonging to any other grade are used for pungent, which is the lowest grade. Spanish paprika is divided into three types (sweet, semi-sweet, and pungent) by pungency, and each type is divided into three grades (extra, select, and ordinary) by colour, ash content and moisture content. The best Spanish paprika is sweet, extra grade, with no pungency, bright fiery red colour and only 8.0% moisture.[5] Microbial contamination by bacteria such as *Bacillus cereus*, *B. subtilis*, and *Clostridium perfringens*,[21-23] yeasts, and aflatoxin-producing moulds such as *Aspergillus flavus*, *A. glaucus*, and *A. niger*[24] have been reported. A total bacterial plate count below 10,000/gram is desirable, with yeast, mould and coliforms below 1000/gram.[25] Major health hazard organisms such as *E. coli*, *Salmonella*, and *Shigella* must be negative. Control by fumigation with ethylene oxide is generally recognized as safe by many countries, as long as fumigant residues do not exceed international standards.[26] Ethylene oxide is toxic and requires special vacuum equipment and technical skill to administer, but it vaporizes rapidly from the material, leaving little residue, and it has no effect on colour, pungency, or flavour, so it is generally considered the most effective method.[25] Paprika that is processed and stored properly generally does not have problems with insect contamination.[27]

8.6.2 Oleoresin quality

The quality specifications for the different types of oleoresin are given in Table 8.2. Three types of oleoresin are specified, based on the pungency and colour values.

Table 8.1 Grades of Hungarian paprika, from best (special) to worst (pungent)[5]

Grade	Quality characteristics							
	Colour	Pungency	Aroma	H_2O	Total ash	Acid-insoluble ash	Ether extract	Powder fineness[a]
				(%)	(%)	(%)	(%)	(sieve #)
1) Special	Bright, fiery red colour	none or very little	pure, very aromatic	10.0	5.0	0.3	12.0	0.45
2) Capsaicin-free (mild table)	Bright red	none some bitterness	pure, sweet	10.0	5.5	0.4	13.0	0.50
3) Delicatesse (table)	Bright red, darker or light	barely detectable	typical pure aroma	10.0	6.0	0.45	14.0	0.50
4) (hot table)[b]	Bright red, darker or light	less pungent	typical pure aroma	10.0	6.0	0.45	14.0	0.50
5) Fine sweet	Dark or yellowish red	less pungent	aromatic	10.0	6.5	0.5	16.0	0.50
6) Semi-sweet	Darker to yellowish red	pungent	less typical aroma	10.0	7.0	0.7	17.0	0.63
7) Rose (pink)	Dull red to pale yellow	markedly pungent	typical aroma	10.0	8.0	0.8	NS[c]	0.63
8) Pungent	Light brown to greenish	very pungent	NS	10.0	10.0	1.2	NS	0.63

[a] 100% of the powder can pass through sieve no.
[b] Similar to Delicatesse, but with a CAPS minimum of 25 mg 100 g^{-1}.
[c] Not specified.

Table 8.2 Essential Oils Association standards for oleoresins[34]

	Type of oleoresin		
Trait	Capsicum	red pepper	paprika
Number	EOA no. 244	EOA no. 245	EOA no. 246
Preparation	Solvent extraction of dried ripe fruit[a]	Solvent extraction of dried ripe fruit	Solvent extraction of dried ripe fruit
Appearance	Clear, red or light amber, viscous	Deep red	Deep red
Odour/taste	very pungent, aromatic	pungent, aromatic	aromatic
SHU	>480,000	>240,000	0
Colour[b]	<4,000	<20,000	40,000–100,000
Soluble in:			
Benzyl benzoate	yes	yes	yes
Alcohol	partly, with oily layer	partly, with oily layer	partly, with oily layer
Fixed oils	yes	yes	yes
Propylene glycol	no	no	no

[a] Residual solvent limits: <25 ppm hexane, <30 ppm ethylene chloride or acetone, or <50 ppm isopropyl or methyl alcohol for all oleoresins.
[b] Colour is determined by measuring the absorbance of a 0.01% solution of oleoresin in acetone at 258 nm. The absorbance value is multiplied by 61,000 to convert to total colour units.

Capsicum oleoresin has very high pungency and low colour, and is used as a source of pungency where colour is not important. Red pepper oleoresin has both moderate pungency and colour, and is used where both traits are important. Paprika oleoresin has very high colour and little or no pungency. Importers of Capsicum oleoresin prefer a pungency value in the range of 6–10% CAPS (1,000,000–1,600,000 SHU).[5] Oleoresin that is processed and stored properly has few problems with microbial or insect contamination.

8.6.3 Dried chilli quality

Like the other forms of peppers used in food processing, colour and pungency are the major quality factors, as well as aroma. Factors that affect the colour of dried chillies include the cultivar, the stage of maturity at harvest and subsequent curing, fruit drying conditions, and the final moisture content. At less than 10% moisture, the colour appears bleached, while at levels greater than 10% there is darkening, possibly caused by non-enzymatic browning. The colour of crushed or ground chilli powder deteriorates faster than whole chillies, due to the auto-catalyzed degradation of carotenoids. The major factor influencing colour retention during storage is the temperature, followed by the moisture content. The effect of air, light, and type of container is minimal. The optimum storage conditions for chilli powder colour retention are −16ºC and 10–11% moisture.[28–29] The American Spice Trade Association (ASTA) has set standards for measuring colour in pepper products that are widely followed. Samples are extracted acetone and the absorbance is read by a spectrophotometer at 460 nm.[30] Values are expressed as ASTA units; a value greater than 200 is considered a very deep red colour. Commercial samples of chilli powder normally range from 100–200 ASTA units, and a premium may be paid by processors for lots with extractable colour greater than 140 units.

The standard for measuring pungency in all forms of peppers is Scoville Heat Units (SHU). The concept was introduced in 1912, when Wilbur L. Scoville, a pharmacologist with Parke Davis, developed the Scoville Organoleptic Test.[6] A panel of five people is used as heat samplers. The panel analyzes a solution made of exact weights of dried chillies dissolved in alcohol and diluted with sugar water. The pungency of the peppers is rated in multiples of one hundred SHU. A majority of three samplers has to agree on one value before any sample is given a value. This method is subjective, especially as it depends on the taster's palate and sensitivity to pungency. Also, the human palate quickly becomes desensitized to CAPS after tasting more than a few samples within a short period of time. It has largely been replaced by high-pressure liquid chromatography (HPLC), which is relatively rapid and reliable compared to the Scoville Organoleptic Test.[31] Results are reported as ppm CAPS, which can be converted to SHU or other units by the following scale: 1 ppm = 16 SHU = 0.0001% = 0.001 mg $g.^{-1}$ Pure capsaicin = 16,000,000 SHU.

Microbial contamination is also a problem in dried chilli, and the same standards used for paprika also apply to dried chilli. In addition, insect contamination can be a problem, particularly the universal drugstore beetle, *Stegobium paniceum* (Linn.) and the cigarette beetle, *Lasioderma serricorn* (Fab.).[32] Insect damage is three-fold, first by the physical loss as frass, second by the loss of quality due to broken pods and loose seed, and third by mould growth and entry of mites due to insect holes in the fruit walls. Control can be achieved by fumigation with insecticidal chemicals, although their use must be monitored carefully and fumigant residues must be within the limits set by international standards.[33] The control method used depends on the quantity, the technological capability and the cost.

8.6.4 Adulteration

Several types of adulteration are possible and have been reported at various times. Whole dried chillies may be adulterated by adding sub-standard dried fruits, which are darkened or bleached, by adding moisture to increase the weight of a load, or by coating with mineral oil or synthetic dyes such as coal tar red to improve the colour and appearance.[5] A more difficult problem is the addition of varieties or harvests that vary in CAPS and colour but have similar shape, size, and visual colour. Only testing of representative samples and sub-samples can determine if a lot is homogeneous. Chilli powder may be adulterated in many ways, some of which are very difficult to detect without sophisticated tests such as HPLC analysis, and 'pure' standards must always be used for comparison. Chilli powder may be adulterated by adding extra amounts of bleached pericarp, seeds, calyx, and peduncle to increase bulk without visibly affecting appearance. Other reported adulterants include artificial dyes, almond shell dust, and dried red beet pulp.

Filth, such as insect fragments, rodent droppings and hairs, and fungal spores are an indication of poor handling and storage. Heavy metals and chemical residues from pesticides represent another adulteration problem. Pesticide residues reported in chilli powder include chlorinated hydrocarbons, DDT, Dieldrin, Endrin, and lindane, but generally in very low levels. Oleoresin may be adulterated by adding synthetic saturated acid vanillylamides such as pelargonic vanillylamide. Detection of these adulterants can be done by sophisticated gas chromatography of the saponified extract[5] or by thin-layer chromatography coupled with HPLC.[8]

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9

Cardamom (small)

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9.1 Introduction

Small cardamom, popularly known as 'Queen of Spices', is the dried fruit of the tall perennial herbaceous plant, *Elettaria cardamomum* Maton, belonging to the family *Zingiberaceae*. It is a shade loving plant cultivated at an altitude of 600 to 1200 m above MSL with an annual rainfall of 1500 to 4000 mm and a temperature range of 10 to 35ºC. Until recently India was the main producer and exporter of cardamom. Of late Guatemala has emerged as a keen competitor to Indian cardamom in the international spice market. Tanzania, Sri Lanka, El Salvador, Vietnam, Laos, Cambodia and Papua New Guinea are the other cardamom growing countries. In India, cardamom is cultivated in the southern states of Kerala, Karnataka and Tamil Nadu. Kerala accounts for 60% of the cultivation and production followed by Karnataka 30% and Tamil Nadu 10%. The physical and chemical characteristerics of cardamom from different growing regions in India is shown in Table 9.1.

Cardamom oil is used in food, perfumery and liquor and pharmaceutical industries as a flavour and a carminative. Its use in the food industry is in flavouring pickles, meat and canned soups. However, the oil is reported to develop some off flavour in a few days when it contacts with air; its use is therefore restricted to fresh meat products and foods with short shelf-life. Increasing use of cardamom oil is reported in compounded flavours for baked goods, sauces and condiments. Cardamom oil is reported to be gaining increasing use in perfumery, with a trend to spicy tones modifying the dominant lavender group perfumes for women (ITC, Markets for Essential Oils and Oleoresins 1974).

Cardamom is used as an adjuvant to carminative drugs. It is officially recognised in British and US pharmacopoeias and used as an aromatic stimulant, carminative and flavouring agent. It can be used to ease cigarette addiction. Eating a few seeds of cardamom can safely be recommended to initially minimise the number of cigarettes being smoked, and slowly the smoker may give up the chronic addiction to chain smoking.

Table 9.1 Composition of cardamom

Region of growth	Weight of 100 capsules (g)	Husk (%)	Seed (%)	Volatile oil (%)	NVEE* (%)	Starch (%)	Fibre crude (%)	Protein (N×6.25) (%)
Karnataka								
Mudigere	23–24	25.5–28.0	72.0–74.5	8.6–8.9	2.0–3.6	47.0–48.0	6.9–6.8	8.8–11.3
Coorg	23–25	26.0–27.0	73.0–74.0	9.1–9.4	2.2–3.1	47.7–48.0	6.7–2.7	10.5
Kerala								
Wynard	20–22	28.0–38.0	62.0–72.0	7.5–10.0	2.2–2.4	39.1–43.7	8.4–9.3	9.7–14.0
Alleppey green	23	27.7	72.3	9.4–9.6	2.2	37.8	–	–
Tamil Nadu								
Yercaud	23–26	27.0	73.0	9.4–9.6	2.4	45.5	7.0	9.8
Nelliampathy	12–18	26.0–31.0	74.0	8.5–10.5	2.5–3.5	43.0–46.0	9.5–12.8	10.7–11.5

* NVEE – non-volatile ether extracts.

Sources: Kasturi and Iyer (1955), Krishnamurthy (1964) and Natarajan *et al*. (1968).

9.2 Description

Cardamom is indigenous to the evergreen rainforests of western ghats of Southern India from where it spread to other tropical countries such as Sri Lanka, Tanzania and a few Central American countries. Presently it is being cultivated in countries lying between 20º latitude north and south. Cardamom was an article of Greek trade during the fourth century BC. It was listed among the Indian spices liable to duty at Alexandria in AD 176 (Rosengarten 1969).

E. Cardamomum exhibits considerable variation under cultivation and the naming of commercial types after the places of production has led to confusion regarding the identity of the varieties. Two varieties based on the size of the fruits are recognized. They are : (1) *E.cardamomum* var. Major Thw. comprising the 'wild' indigenous cardamom of Ceylon or Greater oblong cardamom or long cardamom and (2) *E.cardamomum* var. minor comprising all the cultivated races, particularly those included under the names Malabar and Mysore cardamoms. Var. major is the more primitive variety from which the cultivated var. minor is derived. All the varieties and races are interfertile and the observed variations are probably due to natural crossing. The genus belongs to the natural order Scitaminae, family *Zingiberaceae* under monocotyledons with diploid chromosome number, 2n = 48.

9.2 Production

9.2.1 Harvesting

The peak period of harvest is October–November. The average yield of cardamom is around 150 kg (dry)/ha; however, record yield of 695 kg/ha (average of 9 crop seasons) was obtained by adopting high production technology directly in farmers' plantations (Korikanthimath 1995). Just ripened fruits or physiologically ripened are generally harvested. More splitting of capsules was observed in over-matured capsules

(Korikanthimath and Naidu 1986). Percentage of dry recovery was highest (29%) in the fully ripened capsules followed by the one harvested at physiological maturity (24%) and in immature stage (14%). Capsules may be washed in water to remove the adhering soil and a treatment with 2% washing soda (alkali) for 10 minutes enables retention of the green colour and prevents growth of mould.

9.3.2 Curing

In curing, moisture of green cardamom is reduced from 80% to 12% (wet basis) at an optimum temperature (50º) so as to retain its green colour to the maximum extent.

- *Natural (sun) drying*. This requires 5–6 days and the green colour is bleached by this method.
- *Electrical drier*. Fifty kg capsules can be dried in 10–12 hrs at 45–50ºC retaining the green colour.
- *Flue pipe curing*. This is the convenient method of curing from which high-quality green cardamom can be obtained. The structure consists of walls made of bricks or stones and tiled roof with ceiling. A pipe made of iron or zinc sheet starting from the furnace passes through the chamber and opens outside the roof. The heated air current generated in the furnace passes through the pipe and increases the temperature of the room. The fans located either sides of the wall uniformly spread the temperature. Inside the room the cardamom to be dried is kept in wooden/aluminium trays arranged in racks. The fire in the furnace is adjusted to maintain the temperature between 45–50ºC. Drying takes about 18 to 22 hours (Korikanthimath 1993).

9.3.3 Bleached cardamom

Bleached cardamom is creamy white or golden yellow in colour. It can be done with either the dried capsule or freshly harvested capsules. It is prepared using sulphur dioxide, potassium metabisulphite (25% containing 1% HCl for 30 min) and hydrogen peroxide (4–6% at pH 4.0). However bleached cardamom tends to lose more volatile oil.

9.3.4 Ground cardamom

A large portion of the cardamom imported into western countries is to meet industrial and institutional requirements for bulk supply of ground cardamom (Survey of the World Market, 1977).

Proper maturity reflected by deep brown, shining seeds with satisfactory weight per litre specifications and good characteristic aroma are the factors necessary for making good quality ground cardamom. In cardamom, the presence of the oil cells near the surface which contains aroma-significant components like 1,8-cineole poses special problems due to the high temperatures produced in attrition and grinding. To overcome the loss of volatiles, prechilling and reduced temperature grinding are used (Anon. 1975). A new innovation for idealized grinding of spices is freeze-grinding (−70ºC) which has many advantages; increased retention of volatiles, minimizing oxidation of volatiles, increased throughput and improved functional properties of dispersability of the fine ground material in food preparation (Russo 1976).

Ground spice deteriorates in its aroma quality both by rapid loss of volatile and by the action of oxygen in the head space on the terpenic and lipid components of the spice. This

loss could be controlled by careful selection of packaging materials. Gerhardt (1972) found that of the different packaging material studied, lacquered cans, PVDC and HDPE gave the smallest loss of ethereal oils in powdered cardamom. Koller (1976) found that among several factors influencing flavour quality of vacuum-packaged ground cardamom, temperature not exceeding +5ºC was the most important. Cardamom in powder form could be stored vacuum-packed in laminater such as polyamide/polyethylene or cellophane or lacquered can for 12 months at −18ºC.

9.3.5 Cardamom volatile oil

The most functionally important constituent of cardamom is the volatile oil. The volatile oil content of seeds varies from 6.6–10.6% for the two types of cardamom (cv. Mysore and Malabar) grown in India (Krishnamurthy 1964; Krishnamurthy *et al*. 1967; Korikanthimath *et al*. 1999). In immature capsules the volatile oil content is low, in the order of 4–5%. The husk is reported to yield 0.2% volatile oil, having properties similar to those of seed oil (Rao *et al.* 1925). Yields of the volatile oil varied over a wide range: for seeds from 3.4 to 8.6% and for dried capsules from 5.2 to 11.3%.

Many developing countries have been producing different aromatic volatile oils by steam distillation over a long period. Among the different distillation methods, steam distillation is the preferred method. Esters have been known to be important for cardamom aroma. Other important control factors for obtaining uniform and typical aroma quality of the oil are the rate and time of distillation. Use of top grades of cardamom for distillation of oil is not economical. Lower grades which are good from the point of view of flavour, but do not command high prices as dry capsules because of defects in appearance, are generally used. The less mature, pale brown seeds contain less oil and flavour quality is also different.

The specifications of the Essential Oils Association (EOA), US, which are generally accepted by all countries are given in Table 9.2.

Nambudiri *et al*. (1968) described a stainless steel still, consisting of a material holding cage, condenser and receiver for steam distillators and the conditions of distillation for obtaining acceptable quality oil. Selected material from the lower grades containing seeds of good maturity are first dehusked by shear in a disk mill with wide distances between disks and seeds separated by vibrating sieves. The seeds are again put through the same mill, but closing the distance between the disks to crush the seeds into a coarse powder. The essential oil glands are in a single layer below the epidermal layer and fine milling will result in loss of volatile oil. Freshly powdered coarse grains of cardamom are uniformly and loosely packed into the holding chamber with a perforated bottom. When the cover of the distillation vessel is fitted securely and connected to the tabular condenser, steam at low pressure is let in through a perforated manifold. For efficient distillation, the design of the retort and packing of the powdered cardamom should ensure that the steam passes through the bed uniformly without passing the cage or channelling. Other important controls are the rate and total time of distillation. It was recommended that the distillation be continued for two to three hours.

The large volume of condensate was collected in a cylindrical oil trap which siphoned off the excess water continuously, which if allowed to accumulate, could result in loss of oil by saturation and also cause compositional variation due to differential dissolution of the components. It was found that it is better to keep the condensate warm to get a better separation of volatile oil. The oil floating at the top was collected by lapping through another conical vessel which functioned as a second separator of any residual moisture.

Table 9.2 Specifications for cardamom volatile oil

Definition	Volatile oil distilled from the seeds *E.cardamomum* Maton
Source	Family – *Zingiberaceace*

Cardamom grown in South India, Ceylon, Guatemala, Indonesia, Thailand and South China.

Physical and chemical constants

Appearance:	Colourless to very pale yellow liquid.
Odour and taste:	Aromatic, penetrating, somewhat camphoraceous odour of cardamom: persistently pungent, strongly aromatic taste.
Specific gravity:	0.917 to 0.947 at 25°C
Optical rotation:	+ 22° to + 44°
Refractive index:	1.463 to 1.466 at 20°C

Descriptive characteristics
Solubility
70% alcohol: in five volumes: occasional opalescence
Benzylalcohol: in all proportions
Deithyl phthalate: in all proportions
Fixed oil: in all proportions
Glycerine: insoluble
Mineral oil: soluble with opalescence
Propylene glycol: insoluble
Stability: unstable in presence of strong alkali and strong acids

Containers and storage
Glass, aluminium or suitably lined containers.

Aluminium cans were fitted to the top with the oil to avoid head space, closed tightly and stored in cold chambers.

9.4 Chemical structure

The early work of several authors, summarized by Guenther (1975), shows the presence of 1,8-cineole, d-α-terphenol, terpinyl acetate, limonene, sabinene and borneol. The first detailed analysis of the volatile oil of cardamom was reported by Nigam *et al*. (1965). They used gas chromatography under isothermal conditions and analyzed both the total oil and fractions obtained by fractional distillation and alumina column chromatography. They confirmed and quantified all the hydrocarbon and oxygenated compounds. 1,8-cineole and α-terpinyl acetate are the major components in the cardamom volatile oil. Besides the usual terpene hydrocarbon and alcohols as minor compounds and the dominance of 1,8-cineole and α-terpinyl acetate, it is significant that methyl eugenol also has been identified (Lawrence 1979). The basic cardamom aroma produced by a combination of the major components, α-terpinyl acetate and 1,8-cineole. The percentages of the main components given by Lawrence (1979) are as follows: 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-4-01 (0.9%), α-

terpineol (2.6%), α-terpinyl acetate (31.3%), citronellol (0.3%), nerd (0.5%), geraniol (0.5%), methyl eugenol (0.2%), trans-nerolidol (2.7%).

When the spice is chewed, it does have a slight astringent and pungent taste. The astringent sensation could arise from intense release of many components of the volatile oil when seeds are chewed and or from phenolics that are usually present in seeds. Pungency stimuli have been identified in other spices belonging to the family *Zingiberaceae* to which cardamom belongs, e.g. gingerols and shogaols in ginger and also the saturated compound (6)-paradol from the seeds of the related spices, the *Aframomum meleguta* (Connell 1970).

The most significant component of cardamom, as spice, is the volatile oil with its characteristic aroma, described generally as comphory, sweet, aromatic spicy. The cardamom oil has few mono- or sesquiterpenic hydrocarbons and is predominantly made up of 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, α-terpinyl and linalyl acetates in the composition, make the cardamom volatiles a unique combination. The aroma differences in different sources of cardamom are attributed to the proportion of the esters and 1,8-cineole (Lewis *et al.* 1966; Salzer 1975; Wijesekera and Jayawardena 1973; Korikanthimath *et al*. 1997).

Volatile oil from cardamom *(E.cardamomum* Maton var. *Minisula Barhill*) contains few hydrocarbons and large amounts of 1,8-cineole and α-cineole and α-terpinyl acetate, while that from *E. cardamomum* Maton var, *major* Thewaites (the Ceylon wild cardamom) is high in monoterpenes and very poor in the above two oxygenated compounds. The oils from the Ammomum species are all much higher in 1,8-cineole, around 60 to 75%, and some have relatively large amounts of comphor and borneol. Thus, a complete dominance of 1,8-cineole, camphor, or borneol among the oxygenerated compounds could be identified with the comphory smell.

The flavour characteristics of important volatile components in cardamom are listed in Table 9.3, and the structure of some of the important aroma compounds are shown in Fig. 9.1.

9.5 Quality standards and grade specifications

Dried cardamom require cleaning to remove all stalks and dried remains of floral parts. This should be done by rubbing dried cardamom over a coarse surface of wire-mesh or bamboo trays. This is best carried out while the cardamom is still hot.

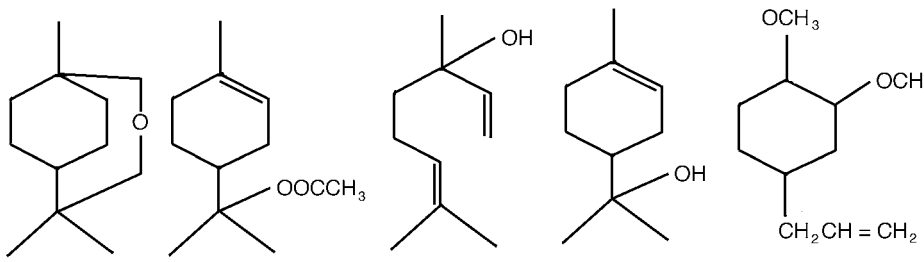

Fig. 9.1 Structure of important aroma compounds.

Table 9.3 Flavour characteristics of important volatile components in cardamom

Components	Flavour description	Effect in flavour use	Use level	Range of concentration (%) in cardamom oil
Esters				
α-terpinyl acetate	Mildly herbaceous, sweet spicy, variation in odour, warm, mild spicy taste.	To stretch cardamom, herbal spice, imitation citrus and cherry, 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, comphoraceous, 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.	Light to heavy perfume; peculiar pleasant taste effect at low levels.	2–10 ppm	1.4–4.5
α-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

Descriptions based on Bernhard *et al*. (1971) and American Spice Trade Association.

With regard to the quality of the dried product, larger, round and uniform pods having a good dark green colour always fetch the highest price. The small type of cardamom with creeping panicles produces round fruits of uniform size and shape, giving a very attractive product. The largest type of bulk gives different kinds of fruits varying in shape and size, from round to longish fruits of nearly an inch in length. This results in a product of mixed quality.

The Government of India and the Indian Standards Institution (ISI) have prescribed fairly well-defined grades, popularly known as 'Agmark' grades and Indian specifications or standards on the basis of important quality factors like colour, weight per unit volume, size and percentage of 'empties', malformed, shrivelled and immature capsules (Tables 9.4 and 9.5).

Table 9.4 Agmark grade designations of 'true' small cardamom

Quality	Grade	Trade name
Alleppey Green cardamom	AGEB	Cardamom Extra Bold
	AGB	Cardamom Bold
	AGS	Cardamom superior
	AGS 1	Shipment Green 1
	AGS 2	Shipment Green 2
	AGL	Light
Coorg Green Cardamom	CGEB	Extra Bold
	CGB	Bold
	CG 1	Superior
	CG 2	Coorg Green Motta Green
	CG 3	Shipment
	CG 4	Light
Bleached and/or half bleached cardamom	BL 1	–
	BL 2	–
	BL 3	–
Bleached white cardamom	BW 1	Mysore/Mangalore Bleachable Cardamom – clipped
	BW 2	Unclipped
	BW 3	Bulk
	BW 4	Bulk cardamom – unclipped
Mixed cardamom	MEB	Mixed Extra Bold
	MB	Mixed Bold
	MS	Mixed superior
	MS 1	Mixed shipment 1
	MS 2	Mixed shipment 2
	ML	Mixed light
Cardamom seeds	CS 1	Prime
	CS 2	Shipment
	CS 3	Brokens

Table 9.5 Specifications for cardamom seeds, India (Indian Standards Institution, New Delhi)

Grade	Trade name	Extraneous matter	Light seeds	Weight (G/l - min)	General characteristics
CS-1	Prime	0.5	3.0	675	Decorticated dry seeds of any variety of *Elettaria cardamomum*
CS-2	Shipment	1.0	5.0	660	
CS-3	Brokens	2.0	–	–	

National and international standards are becoming more and more similar because of close association between the producer and user countries. Specifications for cardamom include the following (Wellner 1972).

1. Cardamom in capsule form should be dried, nearly ripe fruits of *E.cardamomum* Maton. The capsule should be from light green to brown in colour; oblong, rounded or three-cornered in shape; and have a ribbed appearance.
2. The aroma and taste of cardamom in capsules and seeds should be characteristic and fresh and free from foreign aroma and taste, including rancidity and mustiness.
3. Cardamom capsules and seeds should be free from living insects and moulds. Marks on capsules due to thrips infestation should not be counted as insect infestation.
4. Cardamom should be free from visible dirt or dust. Extraneous matter such as bits of calyx, stalks and others shall not be more than 5% by weight in cardamom in capsules and 0.5 to 2% by weight in seeds.
5. The proportions of empty or malformed capsules, from opening and examining 100 capsules taken from the sample, should not be more than 1 to 7% by count.
6. The proportions of immature and shrivelled capsules should not be more than 2 to 7% (m/m).
7. Capsules having black colour and those which are split open at the corners for more than half the length should not be found in the bold grades and not be more than 10 and 15% by count in the 'shipment' and 'light' grades.
8. The proportions of cardamom seeds which are light brown, broken or immature (shrivelled), should not be more than 3 to 5% (m/m).

The importance attached to the different dimensions of quality varies with the primary raw material producer, the intermediary collector, the trader and exporter, the importer, the processor, the distributor and the final consumer. Product quality is generally related to safe moisture level and cleanliness. The content of substandard product and extraneous matter is important to the producer and trader – appearance and colour also to the exporter and importer. The extraction, volatile oil, and specific ingredients are valued by the processor; the interest is sensory quality and cost to the distributor and consumer.

9.5.1 Adulteration

Decorticated seeds can be adulterated with seeds from lower grades and also from large cardamom as they are of similar shape, size and colour. Pale brown coloured seeds would represent immature cardamom which are low in volatiles and poor in quality and intensity. The seeds from large cardamom have lower volatile oil content, 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 showed 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 by microscopy by very different size and structure of the starch granules. Cardamom starch grains, unlike those of cereal and other starches, are very small (2 to 4 m). Whole cardamom powder can be distinguished from the cardamom seed powder by microscopy. 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 Kastner 1974).

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10

Cardamom (large)

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10.1 Introduction and description

Cardamom are the dried seed capsules of a small group of species or plants belonging to the family *Zingiberaceae* which contain seeds possessing a pleasant characteristic aroma and flavour. These are broadly grouped into two categories:

- Small cardamom – popularly known as Chhota Elaichi (*Elettaria cardamomum*) or the true cardamom. It is also known as 'Queen of Spices'.
- Large cardamom – Bada Elaichi (*Aframomum* and *Amomum* species)

Amomum subulatum Roxb. is the greater Indian or Nepal cardamom which is also called large cardamom. It is a native of the eastern Himalayan region. The presence of several wild relatives viz., *A. delbatum*, *A. aromaticum*, *A. kinger*, *A. lingriformi*, and *A. corynostachium* and the tremendous variability within the cultivated species support the view of its origin in Sikkim (Subba 1984, Rao *et al.* 1993, Singh and Singh 1996).

The order *Zingiberales* (formerly known as Scitamineae) to which the family *Zingiberaceae* belongs, appears to have originated as wild plants in the tropical evergreen forests. *Zingiberaceae*, the largest family of this order, is found throughout the tropics but is predominantly Asian. This family has provided important spices which are mostly aromatic, 40 genera and 900 species being recognized. The economically important species which have established themselves as aromatic spices are the genus *Zingiber* (ginger), *Curcuma* (turmeric), *Alpinia* (galanga), *Kaempferia*, all representing rhizomatous spices, and *Elettaria* (small cardamom), *Amomum* and *Aframomum* (large cardamoms) representing seed spices (Anon. 1977).

There has been controversy over the grouping of cardamom. After detailed deliberations the ISO (International Standards Organization) has officially recognized nine species under three main groups (Pruthi 1977):

Group I: *Elettaria cardamomum*
Group II: 4 species of *Aframomum*
(a) *A. augustifolium* (Sonn) K.Schum – Madagascar cardamom
(b) *A. hanburyi* K.Schum – Cameroon cardamom

(c) *A. korarima* (pereira) Engler – Korarima cardamom
(d) *A. melegueta* (Roscol) K.Schum – Grains of paradise or Guinea grains.

Group III: 4 species of *Amomum*

(a) *A. aromaticum* Roxburgh – Bengal cardamom
(b) *A. kepulag*a Spraque et – Round cardamom Burkill, Syn. A. cardamom Roxburgh – or Chester cardamom or Siam cardamom.
(c) *A. krervanh* pierre et Gagnipain – Cambodian cardamom
(d) *A. subulatum* Roxburgh – Greater Indian cardamom, Nepal cardamom or large cardamom

The *Amomum* species are known in the North East Indian and South East Asian countries, while the *Aframomum* species are known in the African regions of Sierra Leone, Guinea Coast, Madagascar and Tanzania. The fruits of the *Amomum* and *Aframomum* are much larger in size in comparison with *Elettaria cardamomum* and it is easy to distinguish them, but the seed size and anatomy are similar in all the three genera.

In this chapter, only *Amomum subulatum Roxburgh* is taken into consideration as large cardamom as it is being cultivated in a larger extent and also due to its position in the trade. From now on, whatever we describe here relates only to *Amomum subulatum Roxb.* (unless otherwise specified).

This species is cultivated in swampy places along the sides of mountain streams in Nepal, Bengal, Sikkim and Assam (eastern Himalayas) and forms one of the cash crops of eastern India. The plants are usually grown along jhoras (small springs), in moist and shady sides of mountain streams and along the hilly slopes, usually at an elevation of 765 to 1675 metres above the mean sea level. The plant is a perennial herb having subterranean rhizomes which give rise to leafy shoots and spikes. The plant matures during the third year of its growth and its height ranges from 1.5 to 3.0 m. Leafy shoots are formed by long sheath-like stalks encircling one another. The leaves are green or dark green, glabrous on both surfaces with acuminate apex. Inflorescence is a dense spike on a short peduncle bearing 40 to 50 flower buds in an acropetal sequence. The fruit is a trilocular many-seeded capsule. The capsule wall is echinated and is reddish brown to dark pink (Rao *et al.* 1993a). Harvesting is usually carried out during August to October.

Dried large cardamom capsules are on an average 25 mm long, oval to globose; greyish brown to dark red brown. The fruit contains 40–50 seeds, held together by a viscous sugary pulp. Though the fruits are clearly identifiable by their larger size and differences in shapes compared with small cardamom, the seeds are of nearly the same size as those of true cardamom. Histological features, sizes and orientation of cells in different layers of husk and seed have been described by Berger (1964, 1965).

There are three popular varieties (cultivars) of large cardamom in Sikkim, viz., Ramsey, Golsey and Sawney. The varietal differences were described by Gyatso *et al.* (1980), Subba (1984) and Rao *et al.* (1993) (see Table 10.1). In addition to these popular varieties, there are several other varieties such as Ramla, Chivey Ramsey, Garday Seto Ramsey, Ramnag, Madhusay, Seto Golsey, Slant Golsey, Red Sawney, Green Sawney and Mingney (Gupta and Borethakur 1986). Rao *et al.* (1993b) reported a promising variety Barlanga from higher altitudes with desirable high yielding characters like maximum ratio of mature tillers to productive spikes (1:3.6) and bold size capsules (with 50 to 80 seeds). Surveys carried out by Biswas *et al.* (1986) revealed that Ramsey and Ramla are well suited to higher altitudes, Golsey for lower altitudes and Sawney widely adaptable to different elevations.

Table 10.1 Characteristics of different varieties of large cardamom

Character/variety	Ramsey	Golsey	Sawney
Altitude	High	Low to middle	Middle
Extent of cultivation	60%	30%	7%
Status	Tall, vigorous wide clump growth	Less vigorous with erect leafy stem bearing stout upright leaves Clumps medium	Tall, vigorous bent, downwards
Stem colour	Maroonish with dense foliage	Greenish to maroonish	Pinkish with dark green foliage
Flowers	Yellowish and small, corolla tip with pink tinge at base	Yellowish orange	Yellowish with pink tinge at base of corolla
Capsules	Smaller (16 to 30 seeds)	Bold to round (40 to 50 seeds)	Medium bold (30 to 40 seeds)
Essential oil	1 to 1.8%	2.3 to 5%	1.8 to 2.5%
Shade requirement	Deep shade	Less shade	Moderate to deep shade
Susceptibility to diseases	Susceptible to Chirkey and Foorkey at lower altitudes	Tolerant to Chirkey and Foorkey but susceptible to leaf spots	Susceptible to viral diseases

Source: Rao *et al*. (1993a)

10.2 Chemical structure

Large cardamom has the following chemical composition. The composition varies with variety, region and age of the product. The fruit on average comprises 70% seeds and 30% skin (Govindarajan 1982, Pruthi 1993).

Moisture	8.49%
Protein	6.0%
Total ash	4.01%
Starch	43.21%
Crude fibre	22.0%
Non-volatile ether extract	2.31%
Volatile ether extract	3.0%
Alcohol extract	7.02%
Volatile extract	2.8%
Water soluble ash	2.15%
Alkalinity of water soluble ash	0.90%
Ash insoluble in acid	0.42%
Volatile oil	2.80%

The volatile oil present in the seeds of large cardamom is one of the principal constituents responsible for providing the typical odour. The essential oil is obtained on steam distillation of crushed seeds and yields 2.5% dark brown coloured mobile liquid with

cineole-like aroma, having the following physical constants: specific gravity at 29ºC, 0.9142, refractive index at 29ºC, 1,460, optical rotation in chloroform −18ºC (Pruthi 1993).

The highest volatile oil content was recorded as 3.32% in variety Golsey Dwarf, whereas the lowest was 1.95% in variety White Ramna (Gupta 1986). Quantitative chromatographic analysis of the composition of distilled essential oil was reported previously by Nigam and Purohit (1960) and by Lawrence (1970). The major constituent of large cardamom essential oil is 1,8-cineole (65–80%) while the content of terpenyl acetate is low (traces to five per cent). The monoterpene hydrocarbon content is in the range of 5–17% of which lamonene, sabeinene, the terpinenes and the pinenes are significant components. The terpinols comprise approximately five to seven per cent of the oil. The high cineole and low terpenyl acetate probably account for the very harsh aroma of this spice in comparison with that of true cardamom (Pruthi 1993).

10.3 The trade in large cardamom

The trade in *Amomum* species is largely confined within Asia, with only very small volumes entering the Middle East, European and North American markets. Mainland China has been and remains by far the principal importer. Large cardamom by smaller volumes have been regularly imported by a number of Arab countries as well as Pakistan, Vietnam, Korea and Japan. Until 1970, the major supplier was Thailand, while minor supplies emanated from Laos, Cambodia (Kampuchea), Nepal and India. Since 1970 Nepal has rapidly increased exports and now matches Thailand in importance.

Figures on overall production of large cardamom are scarce. The global production of large cardamom during 1985–86 was estimated at 7850 tonnes (Anon. 1988). In 1997–98 the annual production of large cardamom in India was in the range of 5000 to 5400 tonnes. The bulk of this is consumed in the country and only one third, about 1700 tonnes, is exported outside India mainly to Pakistan, UAE and Afghanistan (Anon. 1998).

10.4 Cultivation

The main conditions for growing large cardamom are:

- Temperature range (ºC): max. 14–33; min. 4–22
- Season: April–September
- Annual precipitation: 200–250 cm (well distributed throughout the year)
- Altitude range: 765–1675 m above MSL
- Morphology: 4–5 distinct types
- Average life of a plant: 20 years
- Bearing period: max. 6–10 years and steady yield throughout
- Flowering and fruiting: four months from April to July
- Harvesting: September–January; peak period – late October to mid December.

The flowering season starts in May and continues up to August. It takes about four months for the fruits to mature. Harvesting is done by collecting panicles containing ripe fruits with the help of a special chisel-shaped narrow knife, which is specially made for this purpose. Harvesting is done once a year, and because of this there will be some immature fruits in the harvested lot. After harvesting, the individual capsules are

separated from spikes by hand. At the time of harvesting, old sterile dried shoots which do not bear fruits are also removed, by the same knife, locally known as 'Elaichi Chhuri'. During the third year, when first flowering starts in new plantations, the yield of dry fruits is negligible (25 kg or so per hactare). In subsequent years, every year the yield increases until it reaches a maximum in the sixth and seventh year. Yield at this stage varies greatly from 0.3 to 1.0 tonnes of dry cardamom per hectare according to the management and growing conditions of plantations. For one or two years the maximum yield is maintained and then it starts declining to a considerably lower level by the twelfth year. The rate and extent of yield decline again is very much dependent on the management and growing conditions. Some well-managed plantations can yield profitably even up to 20 years (Pruthi 1993).

The capsules are fleshy while harvesting with 72 to 85% of moisture content and the outer layer of the capsules also echinated that can be removed by rubbing after curing. The normal conversion ratio of green to dry capsules is 4:1 to 5:1 which varies according to size and method of curing (Roy 1988). Retention of maroon colour of the capsules is a positive index of quality (Karibasappa 1987, Rao *et al.* 1993a).

10.5 Post-harvest handling

Fruits are separated out of the harvested panicles for drying and curing. Harvested capsules are dried on a mud-plastered threshing floor for seven to ten days, and sold in markets. This contains about 50% moisture and dried again by traders to avoid fungal contamination. Mainly three types of curing systems are available:

- *Traditional 'bhatti' system*. In this system, a load of about 200–250 kg capsules are heaped per m^2 in a 25–70 cm thick bed, and heated directly over a fire by firewood. The bhatti temperature during drying is 100ºC and the drying operation stretches from two to three days. The capsules dried in this system are dark and have a smoky flavour because of direct exposure to heat and smoke. The volatile losses are as high as 35%. The original colour of the capsules is also lost and they cannot be stored for a long time (Roy 1988, Rao *et al.* 1993a). The Central Food Technological Research Institute (CFTRI) has suggested a number of modifications to improve the colour of the 'bhatti'-cured capsules (CFTRI 1994).
- *Flue pipe curing houses*. In this method flue pipes are laid inside a room (curing house) and connected to a furnace installed outside. Fresh cardamom is spread over wire meshes fixed above the flue pipes. This is an indirect system of drying and smoke does not come into contact with the produce at any stage. This type of drier resulted in early drying and gave better quality capsules, including a better colour (Annamalai *et al.* 1988, Karibasappa 1987, Rao *et al.* 1993a).
- *CFTRI system*. The Central Food Technological Research Institute, (CFTRI), Mysore, has designed and developed a low cost natural convection dryer. In this system the flue ducts are arranged in double-deck fashion and connected in series to the furnace. The convection current passes upward through the bed of capsules. Thermal efficiency is much better, the cost of drying cheaper, the quality of the product superior and the annual product output higher, than in the case of a curing house or any other existing system.

The husk of fresh capsules was found to contain 0.49% to 1.16% of anthocyanins. The dried husk contained 0.05 to 0.39% anthocyanins indicating the loss of colour during

drying. Treatment with diluted HCl solution (0.025%) of the freshly harvested capsules, improved the colour after drying as revealed by better retention of the anthocyanin content of 461.43 mg/100 g as compared to freshly harvested ones that contain 1159 mg/100 g (CFTRI 1994).

Large cardamom is usually stored in bulk on bamboo matting spread on the ground or packed immediately into gunny bags which may then be stored in plywood tea-chests. A key issue in storage is maintaining the right level of moisture. The moisture content of capsules has to be brought down to 12–14% to achieve a longer shelf-life (CFTRI 1994). Fully dried cardamom tends to split and also loses its natural taste to some extent, whereas excessive moisture reduces its value. A report by CFTRI, Mysore (1994) states that large cardamom stored over a period of six months tend to lose 4–20% by weight. Insect infestation also reduced the volatile oil content from 2.99% to 1.00%, particularly as a moisture content of 13–15% was found conducive for insect breeding. CFTRI has recommended the use of fumigants like methyl bromide (16 g/m^3), phosphine (1.5 g/m^3), ethyl formate (300 g/m^3) to control all the stages of insect infestation without affecting the quality. CFTRI also recommends the usage of hessian cloth over wrapping of bags, in order to avoid the possibility of direct contamination of the products with the pesticides.

Of several methods available for producing essential oil, steam distillation is ideal using powdered seeds for commercial level production. The essential oil obtained by steam distillation of dry cardamom seeds ranged from 1.5 to 2.5%. An average yield of oleoresin of 4% was obtained by blending essential oil and resin fractions in the ratio of 1:1. Chromatographic tests of the brown resinous residue obtained after steam distillation of large cardamom seeds indicate the presence of triglycerides and steroid compounds (CFTRI 1994). Hydrodistillation has proved to be unsuitable as it generates foam and leads to charring inside the distillation unit.

To improve the flavour of the large cardamom oil, 1,8-cineole, which produces an undesirable odour, can be removed by fractionation, and the oil blended with α-terpinyl acetate, linalyl acetate and genanyl acetate. As an alternative, the essential oil has been blended with small cardamom oil (10%) and α-terpinyl acetate to obtain the pleasant smell of small cardamom. This method has the additional advantage of a threefold increase in the volume of final product (CFTRI 1994).

10.6 Main uses

Due to its pleasant aromatic odour, large cardamom is used for flavouring various vegetables and meat preparation in Indian dishes. It is also used as a flavouring agent in confectionery, hot or sweet pickles and in beverages. Large cardamom seed and powder are used as essential ingredients in mixed preparation and spice masala mixtures. The ripened fruits are considered to be a delicacy and are eaten raw by inhabitants of Sikkim and Darjeeling during September and October months (Gyasto *et al.* 1980, Gupta *et al.* 1984). Large cardamom is also credited with curative properties in Ayurvedic and Unani systems of medicine (Mukherjee 1972, Singh 1978, Anon. 1994)

Essential oil, oleoresin, encapsulated flavour, cardamom cola, large cardamom flavoured biscuits and large cardamom flavoured liquors are some of the products developed for diversifying the uses of large cardamom (CFTRI 1994). Encapsulated flavour is prepared by spray drying a blended solution of large cardamom oil and gum acacia solution. Cardamom cola is prepared by blending caramel acid, large cardamom flavour and carbonating the mixture. Volatile oil of large cardamom, with a mixture of

lemon, lime and ginger flavours, has been blended with distilled rectified spirit to create a liquor product which is compatible with other liquors.

10.7 Quality issues

The quality of large cardamom depends mainly on:

- external appearance, which provides visual perception of quality as influenced by colour, uniformity of size, shape, consistency and texture
- flavour, which is influenced by composition of aromatic compounds. Cineole contributes to pungency while terpinyl acetate towards pleasant aroma (Karibasappa 1987).

A draft International Standards Organisation (ISO) proposal on large cardamom was prepared by Spices Board, India in conjunction with CFTRI, Mysore and submitted to the Bureau of Indian Standards (BIS). The draft proposal for BIS adoption reads as follows:

Capsules

1	Extraneous matter	Not more than 5% by weight
2	Insect damaged capsules	Not more than 5% by weight
3	Moisture	Not more than 14% by weight
4	Volatile oil (%) ml/100 g	Not less than 1.5%
5	Colour should be natural and capsules free from added colours	

Seeds

1	Moisture	Not more than 13% by weight
2	Volatile oil	Not less than 2% by weight
3	Total ash	Not more than 5% by weight
4	Acid insoluble ash	Not more than 2% by weight
5	Extraneous matter	Not more than 2% by weight
6	The seeds should be free from moulds and insects	
7	Insect damaged seeds	Not more than 2% by weight
8	Colour and flavour	Should be natural and characteristic

10.8 References

Readers interested in obtaining further background information on large cardamom are referred to the accounts by Parry (1918), Winton and Winton (1939), Viechoever and Sung (1937), Bouquet and Kerharo (1950), Ferrara (1957), Guenther (1952), Gildemeister and Hoffmann (1956), Berger (1964), Kulkarni and Pruthi (1967), Melchior and Kastner (1974), Singh *et al.* (1978), Govindarajan *et al.* (1982), Rao *et al.* (1993a) and Singh and Singh (1996).

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11

Cinnamon

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11.1 Introduction

The name cinnamon refers to the tropical evergreen tree as well as the bark that is extracted from the plant. Cinnamon is known as *cannelle* in French; *ceylonzeimt/kaneel* in German; *cannella* in Italian; *canela* in Spanish, *yook gway* in Chinese, *dal-chini* in Hindi and *kurunda* in Sinhalese. Cinnamon spice is obtained by drying the central part of the bark and is marketed as quills or powder. The production of cinnamon is mostly limited to the wettest lowland areas of Southeast Asia. Cinnamon is cultivated up to an altitude of 500 metres above mean sea level where the mean temperature is 27ºC and annual rainfall is 2000–2400 mm. It prefers sandy soil enriched with organic matter. Cinnamon is classified in the botanical division Magnoliophyta, class Magnoliopsida, order Magnoliales and family Lauraceae. The tree grows to a height of 7 to 10 m in its wild state and has deeply veined ovate leaves that are dark green on top and lighter green underneath. Both bark and leaves are aromatic. It has small yellowish-white flowers with a disagreeable odour and bears dark purple berries.

The genus *Cinnamomum* has 250 species and many of them are aromatic and flavouring. In many instances, very little distinction is made between the bark of *Cinnamomum verum* (syn. *C. zeylanicum*, true cinnamon) and *Cinnamomum cassia* (Chinese cinnamon). *C. verum* provides cinnamon bark of the finest quality and oil of cinnamon whereas *C. cassia* provides cassia bark and oil of cassia (also known as oil of cinnamon). Cassia was used in China long before the introduction of true cinnamon but is now considered an inferior substitute. There are still other species of *Cinnamomum* which are often traded as cinnamon or cassia.

Cinnamon as a spice dates back in Chinese writings to 4000 BC. The botanical name *Cinnamomum* is derived from the Hebraic and Arabic term *amomon*, meaning fragrant spice plant. Cinnamon is referred to in the Old Testament and in Sanskrit writings. In ancient Egypt, cinnamon was used medicinally, as a flavouring and in embalming. The spice was highly prized by the Greeks and Romans. It was one of the spices which sent Columbus west to discover the eastern Spice Islands. It was the same search for spices that led Vasco da Gama to round the Cape of Good Hope and reach the Malabar Coast of

India in 1498. The Portuguese invaded Sri Lanka immediately after reaching India in 1536 mainly for cinnamon.

Both Herodotus in the fifth century BC and Theophrastus in the fourth century BC believed that cinnamon and cassia came from the neighbourhood of Arabia. *Cinnamomum zeylanicum*, is reported to have originated in Sri Lanka and the Malabar coast of India.[1] *C. cassia* is reported to have originated in South-East China. Other economic species of Cinnamon, which are commonly used as substitute for cinnamon/cassia, are detailed in Table 11.1.

A lot of confusion exists between cinnamon and cassia. While cinnamon and cassia are not precisely the same, they are closely related and the bark of the two is not all that different. It may be a surprise to many to know that what is sold in American stores as cinnamon is mostly cassia. Cassia is thick, hard and has a flavour that is extremely bitter and burning with somewhat of a bite in the after taste. Cassia has a double curl when it dries, meaning that this is a spiral of dried bark, a small bit of relatively straight bark, then the other long edge spiral in the opposite direction. Ground cassia has very reddish brown colour. True cinnamon has but a single spiral curl and is almost papery, brittle, easily crushed or powdered. Its flavour is more subdued, less bitter and has a decidedly sweet finish in the after taste. Its smell is sweet and aromatic. The bark of cinnamon is pale yellowish brown.

11.2 Chemical structure

Cinnamon bark contains:

- moisture 9.9%
- protein 4.65%
- fat (ether extract) 2.2%
- fibre 20.3%
- carbohydrates 59.55%
- total ash 3.55%
- calcium 1.6%
- phosphorus 0.05%
- iron 0.004%
- sodium 0.01%
- potassium 0.4%
- vitamins (mg/100g) B1 0.14; B2 0.21; C 39.8; niacin 1.9; A 175 I.U.

It has a caloric value (food energy) of 355/100 g.[2] It also contains up to 4% volatile oil, tannins constituting of polymeric 5,7,3′,4′-tetrahydroxy flavan-3,4–diol units catechins and pre-anthocyanidins, resins, mucilage, gum, sugars, calcium oxalate, two insecticidal compounds (cinnezalin and cinnzelanol); coumarins and others.[3] The sweet taste of cinnamon is due to the presence of cinnamaldehyde. It is reported that, when combined with sweet food, the sweet sensation of the food is enhanced because of the synergetic effect between the sweet taste of sugar and sweet aroma of cinnamon.[4] Sweetish bark with pungent taste and low mucilage (about 3%) is preferred by the food industry. The deodouring/masking property of cinnamon bark is due to the presence of trimethyl amine.

The bark oil consists of cinnamaldehyde (80–90%), eugenol, eugenol acetate, cinnamyl acetate, cinnamyl alcohol, methyl eugenol, benzaldehyde, cinnamaldehyde, benzyl benzoate, linalool, monoterpene, hydrocarbon, caryophyllene, safrole and others

Table 11.1 Major economic species of *Cinnamomum*

Botanical name	Common name	Origin/centre of production	Part used	Major use
Cinnamomum verum Presl. Syn *C. zeylanicum* Blume	True cinnamon/Ceylon cinnamon	Sri Lanka, Malabar Coast, Seychelles	bark, leaves	Flavouring, perfumery, medicinal
C. cassia Presl.	Cassia, Chinese cinnamon	Southeast China	bark, leaves, buds	Flavouring, medicinal, Chewing pan
C. camphora	Camphor	Southern China/ Indonesia	Wood/ leaves	Medicinal/perfumery
C. loureirii Nees	Saigon cinnamon, Vietnam cassia	Vietnam	bark, bark oil	Flavouring
C. burmanii Blume	Cassia vera, Korinjii cassia	Indonesia	bark (Massoi bark)	Spice and oleoresin in flavouring
C. tamala	Indian cassia	India	bark, leaves	Medicinal, leaves as bay leaves for flavouring
C. ineris	Wild cinnamon of Japan	Japan, Southern India	bark	Mosquito repellent
C. sintok	Java cassia	Java and Sumatra	bark	Flavouring
C. obtusifolium		Northeast India, Myanmar	bark	Substitute for true cinnamon
C. culilawan and *C. rubrum*		Moluccas and Amboyana	bark, bud	Flavouring, substitute for clove bud
C. olivera	Australian cinnamon	Australia	bark	Flavouring
C. glaucascens	Sugandha kokila	Nepal	bark/leaves	Perfumery

such as pinene, phyllandrene, cymene and cineol.[5] Bark oil is a pale yellow to dark yellow liquid with a strong, warm, sweet, spicy, tenacious odour and a sweet, pungent but not bitter taste.

The root bark oil consists of camphor at 60%. It is colourless to pale yellowish brown, similar in odour to stem bark oil but weaker, lacking in fragrance and camphoraceous odour. The leaf oil is a yellow to brownish yellow, with a warm, spicy, somewhat harsh odour, lacking the richness of bark oil. Cinnamon leaf oil has eugenol (80–88%), cinnamaldehyde, cinnamyl acetate, pinene, linalool, eugenol acetate and some minor compounds. The iso-eugenol produced from eugenol fractionated from cinnamon leaf oil possesses more desirable aroma and flavour than that derived from clove leaf oil.[6]

Chip oil has a very good odour and flavour although contains 20% less cinnamaldehyde and twice the amount of eugenol. Seeds contain 33% fixed oil used for making candles. This oil is also called cinnamon suet. Oleoresin is a deep reddish or greenish brown, rather viscous liquid.

Cassia bark yields from 1–2% volatile oil, resembling that of cinnamon. Its value depends on the percentage of cinnamaldehyde. The oil also contains cinnamyl acetate, cinnamic acid, phenyl propyl acetate, orthocumaric aldehyde, tannic acid and starch.

11.3 Production

Sri Lanka followed by the Seychelles and Malagasy Republic are the major producers of true cinnamon bark with the best quality, while Indonesia, China and Vietnam contribute the major share of cassia. India, Malaysia, Indian Ocean Islands and West Union territories are occasional exporters but their impact on world trade is not so significant. The major use of cinnamon is in the form of ground cassia and it comes from Indonesia.[7] The low grade cinnamon comprising feathering and chips is produced in limited quantities in Sri Lanka but constitutes a much larger share of total exports from Madagascar. The major importer of cinnamon is Mexico followed by West Germany, USA and Great Britain. Other importers are Saudi Arabia, Taiwan, Singapore, Hong Kong and France.[8] Spice is traded internationally in whole form and grinding is often carried out in the consuming centres.

Bark oil is produced from the distillation of imported cinnamon/cassia in Western Europe and North America. The major cinnamon bark oil supplier is Sri Lanka, and France is the biggest importer followed by USA.[9] Leaf oil is distilled in Sri Lanka and the Seychelles. USA and Western Europe are the largest markets for cinnamon leaf oil. The ready availability of eugenol ex clove leaf oil has led to some loss in market for cinnamon leaf oil. The major producer of cassia oil is China. USA and Japan are its major importers. Small quantities of cassia oil are produced in Indonesia, Vietnam, India and Nepal but these are obtained from species of cinnamon other than *C. cassia* and are much less widely traded than Chinese oil.

Harvesting for bark is made after the second or third year of planting and the subsequent harvest is made between 12 and 18 months after the previous harvest. Quills of 60–125 kg/ha are obtained from the first harvest. Plants with an age of 10–12 years will give about 225–300 kg quills per hectare. Cutting of the tree is normally done in the wet season from central portions of shoots. The finest quality of bark is obtained from shoots with uniform brown colour, thin bark 1.0–1.25 m length and 1.25 cm diameter. The ideal time for cutting the stem is when the red flush of the young leaves turn to green and this is the indication of the free flow of sap between the bark and the wood. Shoots

ready for peeling are removed from the stumps and the terminal ends of shoots are also removed. The harvesting season varies from May to November, although harvesting on a limited scale continues throughout the year.

11.3.1 Production of quills

There are a number of stages in the production of quills[2]

- *Peeling*: the rough outer bark is first scraped off with a special knife. Then the scraped portion is polished with a brass rod to facilitate easy peeling. A longitudinal slit is made from one end to other and the bark is peeled off. A shoot cut in the morning is peeled on the same day.
- *Rolling*: The barks are packed together and placed one above the other and pressed well. The bark slips are reduced to 20 cm length and are piled up in small enclosures made by sticks. Then they are covered with dry leaves or mat to preserve the moisture for the next day's operation and also to enhance slight fermentation. The retention of moisture is important for the next operation: 'piping'.
- *Piping*: Rolled slips are taken to the piping yard for piping operations. The outer skin is scraped off with a small curved knife. The scraped slips are sorted into different grades according to thickness. The graded slips are trimmed, ends are cut and pressed over pipes. Slips are rolled into pipes and soon after, they are allowed to dry. During drying, smaller quills are inserted into the bigger ones, forming smooth and pale brown compound quills, which are known as pipes. The quills are arranged in parallel lines in the shade for drying as direct exposure to the sun at this stage would result in warping. The dried quills, thus obtained, consist of a mixture of coarse and fine types and are yellowish brown in colour. The quills are bleached, if necessary, by sulphur treatment for about 8 hours.

The process of producing quills has several by-products which are used in further processing:

- *Quillings*: These are broken pieces of quills used mainly for grinding but also for distillation of oil. The pieces vary considerably in size, being about 5 to 15 or 20 cm in length and about 10 to 25 mm in diameter.
- *Featherings*: These are short shavings and small pieces of left overs in the processing of the inner bark into quills. Collectively, featherings present a shade darker colour than the quills and a shade lighter than the chips.
- *Chips*: These are small pieces of bark, greyish brown on the outside and a lighter brown on the inside. They are deficient in both aroma and taste and are not to be compared to the quills for flavour.

11.3.2 Production of ground cinnamon

The heat of grinding is very destructive to the volatile oil content of cinnamon. Cryogenic grinding, however, does retain more volatiles and it is very good in the case of cinnamon.[10]

11.3.3 Production of oils and oleoresins

Distillation of chips and variable amounts of featherings and quillings through hydrodistillation or steam distillation produce cinnamon bark oil. Bark to be distilled

for oil should not be left in wet bundles or become damp, as this encourages mould or fermentation which directly affects oil composition. Cinnamon bark produces two oils, viz. a superior type derived from the inner bark, and a lower quality from broken quills, chips and bark. The leaves left after trimming the cut stems as well as those obtained from pruning operations provide the raw material for production of cinnamon leaf oil. About one tonne of leaves are obtained from one hectare which on steam distillation yields 2.5–3 kg leaf oil rich in eugenol. Cinnamon and cassia oils are both normally rectified to provide oil with a more uniform composition. Rectification is also required to produce feedstock eugenol for subsequent derivative manufacture.

Cinnamon oleoresin is also produced, to a lesser extent especially in North America, from cheaper Indonesian cassia for flavouring purposes. Oleoresin is prepared by extracting cinnamon bark with organic solvents, the yield using ethanol is 10–12% and using benzene is 2.5–4.3%. Recently 1,1,2-trichloro-1,2,2–trifluroethane has also been used.

11.3.4 Storage

Cinnamon should be stored in a cool, dry place. Excessive heat will volatilise and dissipate its aromatic essential oils, and high humidity will tend to cake it. Date the containers when they arrive, so that older stock will be used first. Store them off the floor and away from outside walls to minimise the chance of dampness. Make it a hard and fast rule that all spice containers be tightly closed after each use, because prolonged exposure to the air will also cause some loss of flavour and aroma. Under good storage conditions, the qualities of aroma and flavour for which cinnamon is prized will be retained long enough to meet any normal requirements of commercial baking. Whole cinnamon does not lose its volatile oil as fast as that of the ground form. When ground cinnamon is stored in bulk in an ambient warehouse, a good rule of thumb is loss of 0.1% volatile oil per month. Whole quills will keep their flavour longer. Oleoresin flavour is stable at high temperature. On prolonged storage, owing to oxidation, it becomes contaminated with resin and cinnamic acid and changes to cherry red.

11.4 Main uses in the food industry

A large proportion of the total usage of cinnamon is for culinary purposes. It can be bought as whole sticks, used to flavour rice and meat dishes, but recipes can also call for ground cinnamon. Cinnamon being more delicate is mostly used in dessert dishes. Hot apple cider just does not taste the same without a cinnamon stick. It is used to spice mulled wines, creams and syrups in Europe. In Mexico, the largest importer of Sri Lankan cinnamon, it is drunk with coffee and chocolate or brewed as a tea. Although in Western cuisine, it is mainly used in sweet dishes, its primary use is within savoury dishes in the East. In Indian cuisine, it is used in curries and *pilaus* and is an important ingredient in *garam masala*. Cinnamon sticks are used in beverages, boiled beef, pickles, chutneys and ketchup. It is common in many Middle Eastern, North African dishes in flavouring lamp tagines or stuffed aubergines. Cinnamon does more than add flavour to cakes, cookies, ice creams and other high fat desserts.

In India, Southeast Asia, USA and in European countries, cinnamon is used for flavouring foods. It is commonly used for de-odouring/masking in the food industry in the USA. Bark oil is employed mainly in the flavouring industry where it is used in meat and fast food seasonings, sauces and pickles, baked goods, confectionery, cola-type

drinks, tobacco flavours and in dental and pharmaceutical preparations. The bark oil is anti-fungal and anti-bacterial, slowing meat spoilage, so its use as a spice for meat dishes in warmer climates is sensible. Cinnamon oleoresin is used in flavouring, cake and similar mixes, pickles, prepared meats, convenience foods and related products. Leaf oil is used as a flavouring agent for seasonings and savoury snacks to a small extent. The iso-eugenol, derived from ex-eugenol cinnamon leaf oil, is another flavouring agent in confectionery and liqueurs.

The stronger flavour of cassia is preferred in chocolate manufacture by Germans and Italians and is used less frequently in the kitchen. Cassia oil is used mainly for flavouring cola-type drinks, with smaller amounts used in bakery products, sauces, confectionery and liqueurs. Dried unripe fruit, or Chinese cassia buds, have the odour and taste of the bark, and are rather like small cloves in appearance. They are employed in confectionery and in making pot-pourri. Cinnamon buds are as good for flavouring and spicing as the bark itself.[11]

Cinnamon is used widely in baking both for colouring and flavouring. When purchasing cinnamon, however, the commercial baker must consider his specific needs. For certain purposes, it may be desirable to give a baked product high cinnamon colouring and yet only relatively mild cinnamon flavouring. In this case, the buyer would look for a red-coloured cinnamon (cassia) with a moderate oil content, or perhaps a cinnamon blend (in which two or more grades are mixed to give a desired performance). The blending of different cinnamon varieties or grades to create tailor-made cinnamon for various types of baked goods has become a standard practice. It is something which commercial bakers have requested and provided the blends are formulated properly, they have many advantages.

11.5 Functional properties and toxicity

This herb has been used medicinally for thousands of years to fight toothache, clear up urinary tract infections and soothe stomach irritation. It has a broad range of historical uses in different cultures including the treatment of diarrhoea, arthritis and various menstrual disorders. The large number of medicinal applications for cinnamon indicates the widespread appreciation of folk herbalists for its healing properties.

In the Indian System of Ayurvedic medicine, it is used against a wide spectrum of diseases like bronchitis, colds, congestion, diarrhoea, dysentry, oedema, flu, gas, metabolic and heart strengthening, hiccups, indigestion, liver problems, menorrhagia, melancholy, muscle tension, nausea and vomiting. It assists uterine contractions during labour and menstrual pain from low metabolic function. For external applications, it is used against headaches and pain.[12]

In Unani medicine, it is used as a cephalic tonic and cardiac stimulant and for the treatment of coughs. Flowers are used in the European tradition as a blood purifier. Cinnamon may find its way to a diabetic's daily diet. It contains a chemical called methoxy hydroxy chalcone polymer, which can reduce the blood glucose level. Cinnamon is used for religious purposes also. Its believed, by some, that burning cinnamon incense will promote high spirituality and aid in healing. Some people believe that it can stimulate the passions of the male.[13]

It is now becoming more widely used as a herbal remedy in Europe and the United States. The generally recommended medicinal dosage for cinnamon powder is 0.5–1 g as tea, 0.5–1 ml as fluid extract in 1:1 in 70% alcohol and 0.05–0.2 ml bark oil.[14]

Cinnamon is a good detoxifying herb and acts as a pain reliever. Various terpenoides found in essential oil are believed to account for cinnamon's medicinal effects. Important among these compounds are eugenol and cinnamaldehyde. The essential oil also shows antimicrobial activity against *Pseudomonas*, *Aspergillus parasiticus*, *Staphylococcus aureus*, *Candida* and *Saccharomyces cerivisiae*, *Serratia* and gram positive (Bronchothrix, Carnobacterium and Lactobacillus). The bark oil is anti-fungal and anti-bacterial.

Cinnamon oil has strong lipolytic properties in dissolving fat and thus aids digestion.[15] Once consumed, cinnamon helps break down fats in the digestive system, possibly by boosting the activity of digestive enzymes. Cinnamon also has a potential role in the treatment of diabetes. Cinnamon contains a chemical called methoxy hydroxy chalcone polymer which can reduce the blood glucose level.

Culinary cinnamon is on the Food and Drug Administration's list of herbs generally regarded as safe. The amounts of cinnamon normally used in food are non-toxic, although some people develop allergic reactions after eating this spice. Chronic use may cause inflammation in the mouth. Ingestion of cinnamon oil may cause nausea, vomiting and possible kidney damage. The oil may cause redness and burning of the skin. Do not use in case of fever and pregnancy. Cinnamon handlers have a high incidence of asthma, skin irritation, and hair loss. Toothpastes and ointments containing cinnamon may cause stomatitis and dermatitis in some cases.

Only small amounts should be used initially in persons who have not previously had contact with cinnamon, and anyone with a known allergy should avoid it. The concentrated oil is more likely to cause problems. It has been reported from Sri Lanka that workers undertaking grading of cinnamon have suffered a number of ailments, mainly in the form of cough and asthma, smarting of the eye and irritation to the skin due to exposure to cinnamon dust.

11.6 Quality issues

The quality of bark is greatly influenced by the soil and ecological factors. The bark obtained from the central branches is superior to that from the outer shoots and that from either the base or the top.[16] The bark of thick branches is coarse and that of young shoots is thin and straw coloured with very little flavour.[17] Plants grown under shade produce inferior quality quills.

The quality of cinnamon is assessed primarily on the basis of its appearance and on the content and aroma/flavour characteristics of the volatile oil. Good quality cinnamon should not be thicker than a thick paper. It should be light brown with wavy lines and produce a sound of fracture when broken. When chewed it should become soft, melt in the mouth and sweeten the breath. Freshly ground cinnamon bark of good quality contains 0.9 to 2.3% essential oil depending on the variety.

11.6.1 Grading of quills

This is essentially done on the basis of physical appearance and there is no close relation with the volatile oil content. Compound quills measuring 42 inches long (just over 1 m) are sorted into grades according to the thickness of the bark. Three main qualities are exported[18] namely:

- Fine/continental grades: Quills are fine and are designated by a series of zeroes C-00000 being the thinnest and best, while C-0 is the thickest (range from 10 mm in diameter or less in C-00000 and 19 mm in C-0 grade)
- Hamburg grades: H1 to H3 wherein H-1 grade is thicker and darker than C-0 grade. H-3 is very coarse, ranging from about 23 mm to 32 mm
- Mexican grades: M-00000 and M-0000 are intermediate in quality between fine and Hamburg grades. M-00000 is equivalent to C-000 in thickness and M-0000 is equivalent to C-0.

For cassia quills, the grade designations are:

- Quality A: quills 1 m long taken from the main trunk
- Quality B: from side branches
- Quality C: broken pieces

11.6.2 Quality specifications

Whole and ground cinnamon quality is defined in ISO 6539-1983 for its physical and chemical properties. According to this standard, Sri Lankan cinnamon should have:

- moisture (max) 12%
- total ash (max) 5%
- acid insoluble ash 1%
- volatile oils: whole – 1% and ground – 0.7%

The American Spice Trade Association (ASTA) has suggested moisture levels to be at 14% for all *Cinnamomum* species. Most good quality cinnamon should have ash and acid insoluble ash levels less than 5% and 1% respectively. Insect fragment levels mandated by the Food and Drug Administration (FDA) must be less than 400 per 5 g in the ground spice and the minimum volatile oil content of the fortified ground cinnamon/cassia shall be 2.0 ml per 100 g. The FDA has set defect action levels of contaminants for cassia/cinnamon as:

- an average of 5% mouldy pieces by weight
- an average of 5% insect infested pieces by weight
- an average of 1 mg of excreta per pound of cinnamon.

British Pharmacopoeia, 1973, lays out the following specifications for bark of Ceylon cinnamon:

- acid insoluble ash should not be more than 2.0%
- foreign organic matter, not more than 2.0%
- volatile oil, not less than 1.0% v/w.[19]

There is no international standard for cinnamon bark oil although batches containing cinnamaldehye at the higher end of the range fetch higher prices. In USA the Essential Oil Association standard specifies an aldehyde content of 55–78%. However, International (ISO) standards exist for cinnamon leaf[20] and cassia oils.[21] Sri Lanka now accounts for almost all of the leaf oils in the international market and specifies 75–85% eugenol content and the maximum of 5% cinnamaldehyde. In the United States an FMA monograph, which replaces the old EOA standards, specifies the eugenol content of leaf oil in terms of solubility in KOH (80–88%). For cassia oil, cinnamaldehyde is the major constituent and a minimum content of 80% is specified in the ISO standard.

11.6.3 Adulteration

Cinnamon is frequently adulterated with a rougher, thicker and less aromatic bark from cassia and *C. tamala*. Bark oil is usually adulterated with leaf oil. Artificial cinnamon was prepared by Schmal in 1940, mixing 3.4% of a mixture of 96% cinnamaldehyde and 4% eugenol with a carrier such as powdered hazelnut or almond shells and colouring the mixture with yellow brown dye.[22] Bark oil is often distilled from a mixture of bark and leaves. Bark powder is adulterated with powdered beechnut husks, aromatised with cinnamaldehyde. It may often also be adulterated with sugar, ground walnut shells, *galanga* rhizome, etc. The addition of cassia oil to cinnamon bark oil represents another form of adulteration. The oil sometimes contains resin, petroleum or oil of cloves.[23]

True cinnamon can be detected by TLC by European/American distillery criteria, where limit of bark oil eugenol content should not exceed 14%. The cinnamaldehyde should fall between 60–75%. Ceylon cinnamon, if tested with one or two drops of tincture of iodine to a fluid ounce of a decoction of the powder, is but little affected, while with cassia a deep blue black colour is produced. The cheaper kinds of cassia can be distinguished by the greater quantity of mucilage, which can be extracted by cold water.

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12

Clove

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12.1 Introduction

The clove, *Syzygium aromaticum* (L.) Merrill et. Perry, belongs to the family Myrtaceae. The species is indigenous to certain volcanic islands of North Molucca, in the eastern part of Indonesia, where cultivated varieties and wild forms are found, that is Ternate, Tidore, Motir, Makian and Bacan, and the western part of Irian Jaya, where a considerable wild population occurs. The common synonyms are *Caryophyllus aromatica* L., *Eugenia aromatica* Kuntze, *E. Caryophyllata* Thunb. and *E. Caryophyllus* (Sprengel) Bullock & Harrison.

The tree is of medium size, fine, evergreen, reaching up to 20 m in height and varies in its canopy shape from cylindrical to pyramidal, depending on the variety. The tree can live up to 100 years and there are individual records of trees over 350 years old in Ternate. The trunk diameter can reach 30 cm in mature plants. The leaves are opposite, oblong obovate in shape, bright pinks in newly-formed leaves which turn to dark green when mature. The inflorescent is a terminal, with flowers borne in clusters, varying in flower numbers from 15 to 50, depending on variety and cultural practices. The flower is a hermaphrodite with a fleshy hypanthium that is surmounted by the sepals. The colour of unopened buds at the young stage is usually green, turning to flushed pink when they reach their full size, at which time they are ready for harvest. At that stage the stamens are still inside and covered by the petals which form the head of the dried cloves. Early picking or overripe buds will produce lower quality clove bud (Table 12.1). The tree is grown primarily for the unopened flower buds which are dried to produce the familiar spice of commerce.

The main products of clove are:

- whole or ground clove buds
- essential oils, produced from clove buds, stem and leaf
- clove oleoresins.

Whole or ground clove contains 15 to 20% by weight of volatile oil. The major components of clove bud oil are eugenol 70–95%, eugenol acetate up to 17% and 12–15% β-

Table 12.1 The characteristics of clove bud from Zanzibar type at several stages of maturity

Characteristic	Bud maturity stage			
	Fallen flower	Undeveloped bud	Fully developed bud	Overripe bud
Clove bud				
Water content (% v/b)	12.3	5.0	12.8	6.5
Oil content (% v/b)	13.9	14.9	16.4	16.1
Ask content (%)	4.7	3.8	4.7	6.11
Fibre content (%)	11.8	10.8	8.5	13.3
Si content (%)	0.15	0.11	0.11	0.10
Clove bud oil				
Total eugenol content %*	91.0	90.0	94.0	93.0
Eugenol content (%)**	54.2	55.6	68.5	72.2
Eugenol acetate content (%)**	34.4	36.5	22.0	9.4

Notes:
* Cassia method.
** By gas chromatography
Source: Balittro (1986) in Nurdjannah *et al*. (1977).

caryophyllene. For clove stem oil (the flower stem contains 5–7% oil by weight), the principal component is still eugenol 90–95%, others being eugenol acetate and caryophyllene at lower amounts. Clove leaf oil (comprising up to 3% oil by weight) is a rather lower quality oil than the former and is less expensive, with the principal component being eugenol 80–88%. The chemical structures of eugenol, eugenol acetate and β-caryophyllene are illustrated in Fig. 12.1.

12.2 Production

The world annual demand stays at 4 000–5 000 t, with the USA consuming 1850 metric tonnes in 1990. Indonesia became the world's largest producer of cloves in 1996 with total production 90 000 t, mostly consumed by the Indonesian kretek cigarette manufacturers, with exports of 9 000 t. Despite a rapid increase in Indonesian clove production, Zanzibar and Madagascar remain the main sources for international markets

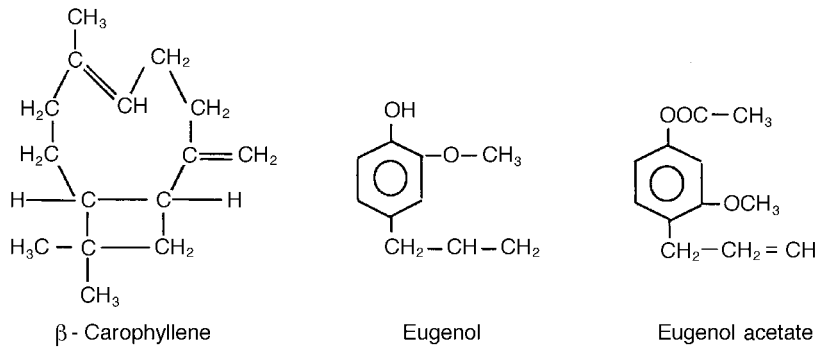

Fig. 12.1 Chemical structures of eugenol, eugenol acetate and β-carophyllene (Guenther 1950).

with 15 000 t in Madagascar and 6 000 t in Zanzibar (Verheij and Snijders 1999). Several thousand tonnes are produced by other Asian countries such as Sri Lanka, India and Malaysia, and smaller amounts by other African countries.

12.2.1 Dried clove bud

Clove buds are harvested when they have reached their full size and the colour has turned reddish. After being harvested, the buds are separated from the stems, by hand or thresher machine. The thresher machine produced by the Research Institute for Spice and Medicinal Crops (RISMC), Indonesia, with 1 hp electric power could separate 76 kg fresh clove bud/hour. Immediately after separation, the buds are dried under the sun or using an artificial dryer. The colour and oil content of artificially dried cloves are not significantly different from sun dried (Hidayat and Nurdjannah 1992).

12.2.2 Storage

Dried whole clove bud is usually packed in gunny bags and should be stored in a clean, dry room with good ventilation. This way of storing should not cause any significant changes except loss of sheen. Storage usually causes loss of oil by evaporation, the rate depending on the physical condition of the spice, mainly the moisture content of the products, temperature and relative humidity during storage (Purseglove *et al*. 1981). The essential oil and eugenol acetate content of whole clove decreased slightly after storing for six months, while eugenol content increased (Table 12.2). Loss of volatile oil during storage from whole clove is relatively slow compared to ground clove. Ground clove is more sensitive to high ambient temperature and moisture content which can change its stability and flavour value. Moisture content and temperature storage of ground clove should fall within 8–10%, and 10–15%, respectively, with relative humidity 55–65%. Poor storage conditions could cause more loss of volatile oil, mould growth and development of musty flavour and odour (Reineccius 1994).

Storage can also change the composition of carbon dioxide extracted clove bud. Reduction in caryophyllene content is 11% at 0±1°C, while at ambient temperature reduction of CO_2 extracted oil is higher (up to 18%) compared to commercially distilled oil (only up to 13%) (Gopalakhrisnan 1994). Moreover eugenol content increased after storage, whereas eugenol acetate remained fairly constant (Table 12.3).

Table 12.2 The changes of quality of dried clove bud during storage

Place of origin	Storage duration (months)	Oil content of clove bud (%)	Clove oil *	
			Eugenol content (%)	Eugenol acetate content (%)
Samalayu	0	17.22	78.30	7.97
	6	16.48	80.25	6.80
Cigombong	0	17.04	77.56	11.20
	6	14.10	78.10	8.78

* Analysis using gas chromatography.
Source: RISCM (1988).

Table 12.3 Changes in composition of CO_2 extracted clove bud oil during storage

Component	Days of storage							
	Carbon dioxide extracted oil (%)					Commercial distilled oil (%)		
	0	45	90	45	90	0	45	90
α-cububene	1.5	1.1	1.3	1.2	1.2	0.7	0.7	0.6
α-copaene	1.7	1.4	1.5	1.4	1.4	1.0	1.0	1.0
caryophyllene	16.6	15.0	14.7	15.1	13.6	10.8	10.5	9.4
eugenol	62.2	61.4	64.8	61.3	65.7	71.0	70.1	72.6
isoeugenol	0.9	0.9	0.8	0.8	0.6	0.6	0.6	0.5
nerolidol	1.2	1.2	1.2	1.2	1.2	0.4	1.2	1.1
eugenol acetate	14.3	13.8	13.6	14.6	13.6	12.1	13.4	12.3
farnesol	0.1	0.3	0.3	0.4	0.3	0.2	0.3	0.4
MVMC	0.2	0.1	0.3	0.1	0.2	0.1		0.1
LVMC	1.1	2.7	1.4	3.6	2.2	2.2	2.3	1.8

Source: Gopalakhrisnan (1994).

12.2.3 Ground clove

Ground clove is produced by milling and/or grinding of the dried clove buds. The process is usually conducted at low temperature (25º–35ºC) to prevent the loss of valuable volatile constituents during processing. Various techniques such as pre-chilling, water cooling or refrigeration of the grinding chambers have been developed to minimize the heat formed during processing. The results are powder with several degrees of fineness, depending on the nature of the spice, the ultimate application and the country. For extraction and distillation, coarsely ground material are accepted, while for direct use in food seasonings, a finer product is required. To obtain a very fine clove powder a two-step procedure is usually conducted; the buds are firstly reduced to a very coarse powder by passage through a slow speed breaker or cutter mill, then they are ground to the desired fineness. The United States requires finer powder than the United Kingdom.

12.2.4 Clove oil

Depending on the raw material, three kinds of oil are produced. The yield and quality of the oils are influenced by origin, variety, quality of raw materials, pre-treatment before distillation, distillation method, and post-distillation treatment. Clove buds and stem are comminuted before distillation to break the oil cell and widen the surface so that the oil can be released more easily from the cells. Clove leaf does not need pre-treatment as it is already in thin form. The materials are distilled using water and steam or steam distillation for between 8 and 24 hours. The highest yield derived from high quality clove bud (±20% oil content) is 17%. In the United Kingdom, the finest oil is obtained by water distillation containing 85–89% eugenol (Purseglove *et al*. 1981).

According to Gildemeister and Hoffimer, cited by Guenther (1950), the distillation of whole clove bud produces clove oil with high eugenol content, and specific gravity above 1.06. Comminuted clove buds produce clove oil with a slight lower eugenol content, and specific gravity lower than 1.06, because evaporation of the oil occurred during comminution. To prevent evaporation, distillation of comminuted material should be done immediately. Belcher (1965) stated that the eugenol content of the oil is dependent

on the time taken to distill the charge. Rapid distillation produces oil with eugenol content far higher than that normally found in commercial practice. Commercially CO_2 can be used to extract clove bud oil at subcritical condition using extraction conditions of 50–80 bar pressure and temperature 0 to 10ºC. This method is used as an alternative to steam distillation. The oil product has better characteristics, i.e. no solvent residue, no off notes, more top notes, more back notes, better solubility and concentration of aromatic components (Moyler 1977).

Clove stem oil of Indonesian clove, using water and steam distillation, yield 5–6% with eugenol content 90–98%, variation in yield and eugenol content dependent on distillation time (Nurdjannah *et al*. 1990). According to Purseglove *et al*. (1981), in Zanzibar, distillation using stainless steel steam stills, which hold 680 kg of steam for 16 hours yielded 5–7% of almost water white oil. The colour darkens to yellow, sometimes violet-tinted, as the oil ages.

Clove leaf oil is usually produced from dried fallen leaf (in Indonesia) or fresh leaf after trimming the upper part of the clove tree (in Zanzibar). The oil may vary considerably in composition but eugenol content is usually 80–88%, with low eugenyl acetate and high content of caryophyllene. Distillation of leaf in a 100 l still capacity for eight hours yielded 3.5% oil with total eugenol content 76.8% (water content 7–12%) (Nurdjannah 1993).

12.2.5 Oleoresin

Clove oleoresin prepared by solvent extraction of clove bud, yielded about 18–22% oleoresin (90–92% volatile components) using benzene and 22–31% using alcohol (Weiss 1997). Ground clove is extracted by suitable solvent(s) then evaporated or distilled to obtain oleoresin. According to Somaatmadja (1981) ethanol is a very safe solvent because it is not toxic. Oleoresin is an extremely concentrated product, containing all the flavouring ingredients soluble in the particular solvent used, so that much closer to the original clove odour and flavour (Heat 1973). Oleoresin can also be produced by supercritical CO_2 extraction, which is conducted at 200–300 bar pressure at 50–80ºC. *In situ* fractionation is possible at 80–100 bar and temperature 0–50ºC. This could extract all the soluble components of oleoresin in a similar way to organic solvent extraction. The product is free of solvent residue(s), and can be further fractionated to produce oil. Solvent(s) extraction is, however, more cost effective than supercritical extraction (Moyler 1977).

12.3 Main uses in food processing

The use of clove in whole or ground form is mainly for domestic culinary purposes and as a flavouring agent in the food industry. Clove can also be used as food. Whole cloves are seldom used in food processing as they are not a ready source of flavour. In some cases, whole clove is inserted into ham and baked apples, and for pickles. Usually only small amounts, perhaps as many as five whole cloves are used for pickling sauce blend, for meat such as corned beef and stews.

In the food industry, cloves are often used in the form of ground, extracted essential oils or oleoresin in a small amount because of their intense flavour. The advantages of using ground cloves is that they retain a considerable degree of their original stability during storage and are better able to withstand high-temperature processing (e.g. baking)

than many of the extracted processed products. Oleoresin is preferred over other clove products, because it contains both volatile essential oil as well as non-volatile resinous material, which accounts for the flavour mimicking the original ground spice. Oleoresin also has low risk of bacterial contamination.

Food products which use clove are mainly curry powder, sauces and baked foods. According to Farrell (1990) curry powder uses 2% (mild) to 3% (sweet) by weight of ground clove buds, meat sauces 0.37% clove ground or 0.111% clove oil, food seasonings such as Bologna seasoning A, B and C use 0.39% ground clove, 0.07% clove oil, and 0.45% clove oil, respectively. Chili sauce uses 0.025% oil, mustard 0.111% and 0.222% ground clove in Dijon and Dusseldorf, respectively, tomato ketchup uses 0.139% clove oil, whereas sausages (Sweet Italian) use 0.111% ground clove (Farrell 1990). The highest average maximum use level reported for cloves is 0.236% in condiments and relishes, and 0.06% clove stem oil and 0.078% clove bud oleoresin in alcoholic beverages (Leung 1980).

Clove leaf oil is not suitable for food flavouring because of its harsher note, and does not reproduce the genuine clove flavour. It is mainly produced for production of eugenol and caryophyllene (Weiss 1997). Eugenols have flavour and antiseptic properties, therefore they have been used in soaps, detergents, toothpaste, perfumery and pharmaceutical products. Maximum use levels of bud and stem oils are 0.15% and 0.25% in soaps, 0.7% and 1.0% in perfumery. The major use of clove is, however, in the manufacture of kretek cigarettes in Indonesia which accounts for more than 90% of Indonesian clove production.

12.4 Functional properties

Besides being a source of natural flavour, cloves also contain nutrients, such as proteins, vitamins, minerals, etc. The composition of nutrients in 100 g is illustrated in Table 12.4.

Table 12.4 Nutritional composition of clove, per 100 g

Composition	USDA (ground)	ASTA
Water	6.86	5
Food energy (kcal)	323	430
Protein (g)	5.98	6.0
Fat (g)	20.06	14.5
Carbohydrate (g)	61.22	68.8
Ash (g)	5.88	5.0
Ca (g)	0.646	0.7
P (mg)	105	110
Na (mg)	243	250
K (mg)	1102	1200
Fe (mg)	8.68	9.5
Thiamin (mg)	0.115	0.11
Riboflavin (mg)	0.267	ND
Niacin (mg)	1.458	1.5
Ascorbic acid (mg)	80.81	81
Vitamin A activities (RE)	53	53

Source: Tainter and Grenis (1993).

It appears that clove contains fat and carbohydrate in high concentration and has relatively high food energy.

Clove has long been used in traditional medicine, particularly to aid digestion, cure stomach disorders and in pain relief (Rosengarten 1969; Rumphuis 1741). Some of these therapeutic properties have been investigated, particularly the role of eugenol as an antiseptic. Clove oil has been used successfully for inflamed oral and pharyngeal mucous and for topical anesthesia in dentistry. RISMC has also successfully made balm with clove oil as the active ingredient which is used for soothing pain caused by rheumatism (Nurdjannah *et al*. 1997). The oil is also a potent bactericide, nematicide and fungicide.

It is believed that clove has antioxidant properties, which can neutralize free radicals associated with cancer. Antioxidant content varies depending on the type of clove product. Ground clove contains 1.8%, while in soluble fraction 1.4% (petroleum ether soluble fraction) and 1.7% (alcohol soluble fraction).

Shahidi *et al*. (1995) reported that the antioxidant activity of ground clove, ginger, oregano, sage and thyme in meat lipids was concentration dependent, but clove was most effective, followed by sage and then rosemary. Ginger and thyme exerted the weakest effect.

Gallic acid and eugenol **110** have been identified as the major components in clove (*Eugenia caryophyllata*) (Kramer 1985). It has been established that *iso*-eugenol **111**, more rarely found in nature, exhibited higher antioxidative efficiency than eugenol during methyl oleate (Davcheva *et al*. 1992) and sunflower oil oxidation (Ivanov and Davchera 1992). Eugenol and *iso*-eugenol also have an inhibiting effect on the peroxidation of lecithin induced by the Fe^{2+}-H_2O_2 system (Toda *et al*. 1994).

Table 12.5 Whole clove chemical and physical specification

Organization	Suggested limit	
	Whole clove	Ground clove
ASTA cleanliness specification:		
Whole dead insect by count	4	—
Mammalian excreta, by mg/lb	5	—
Other excreta, by mg/lb	8.0	—
Mould, % by weight	1.00	—
Insect defiled/infested, % by weight	1.00	—
Extraneous, % by weight	1.00	—
A 5% allowance for unattached clove stems over and above the tolerance for other extraneous matters is permitted		
FDA DALs:		
Adulteration with stem by weight	Ave. of 5%	
Volatile oil	16. 0% min.	14.0% min.
Moisture	8.0% max.	8.0%
Ash	5.0% max.	5.0%
Acid insoluble ash	0.5% max.	0.5%
Military specification (EE-S-635J)	5% or more by weight of stem	—
Average bulk index (mg/100 g)	240	—

Source: Tainter and Grenis (1993).

Table 12.6 Specifications of oil of cloves

Characteristics	Sources of oil		
	Flower bud	Flower stem	Leaf
Colour	colourless to pale yellow	yellow to dark brown	straw coloured or very pale
Specific gravity (25°/25°C)	1.038 – 1.060	1.048 – 1.056	1.036 – 1.046
Optical rotation (20°C)	−1° 30′ to 0	−1.5° to 0	0 to −2°
Refractive index (20°C)	1.527 – 1.535	1.534 – 1.538	1.531 – 1.535
Solubility (70% ethanol)	2 vol	2 vol	2 vol
Total phenols (min. by volume)	85%	89 – 95	84 – 88

Source: Reineccius (1994).

12.5 Quality and regulatory issues

The quality required for clove products depends on each country, for use in domestic or export and nature of the product. The ASTA (American Spice Trade Association) and FDA (Food and Drug Administration) recommendations for whole spice are described in Table 12.5. The specific requirement for clove ground is 12% for minimum quercitannic content, clove stem content maximum 5%, and volatile ether extract minimum 15% (Reineccius 1994). For clove oil, specifications are illustrated in Table 12.6. For oleoresin, Salzer (1975) recommended determination of volatile oil content and subsequent assay of eugenol content as the measure of quality. There are specifications on the maximum residues limit in the foodstuff as a result of the use extraction solvents on the preparation of food flavourings from natural flavouring materials which should be applied to solvent extracted clove oleoresin (Table 12.7).

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Table 12.7 The maximum solvent residues limit in foodstuff

Solvent name	Max. residue limits (mg/kg)	Solvent name	Max. residue limits (mg/kg)
Diethyl ether	2	Ethyl methyl keton*	1
Hexane*	1	Dichloromethane	0.02
Methyl acetate	1	Methyl-propan-1-ol	1
Butan-1-ol	1	Propan-1-ol	1
Butan-2-ol	1	Cyclohexane	1

* Combined used is forbidden.
Source: Ziegler and Ziegler (1998).

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13

Cumin

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13.1 Introduction

Cumin is a strong aromatic of dried ripe fruit (seed) of *Cuminum cyminum* L. (Apiaceae). It is variously known as: cumin, kummel, comino, zireh-e sabz, cumino, kemon, zira, kamun. Cumin is mentioned in Isaiah xxvi. 25 and 27, and Matthew xxii 23, and in the work of Hippocrates and Dioscorides. From Pliny we learn that the Romans took ground seed medicinally with bread, water or wine. In the thirteenth and fourteenth centuries, it was much in use as a culinary spice.

Cumin is indigenous to northern Egypt, the Mediterranean region, Iran and India. Today it is cultivated in Mediterranean countries, Saudi Arabia, Iran, India, Mexico and China. Nowadays most cumin is grown in Iran, Sicily, India and Malta. Cumin is a mixture of united and separated mericarps; yellowish green or yellowish brown, elongated ovoid; 3–6 mm in length. The surface has five primary ridges alternating with four less distinct secondary ridges bearing numerous short hairs. Some fruits have a short attached stalk. These fruits (seeds) belong to a small annual herb 15 to 50 cm in height, with long slender and white roots, bidivaricated branching stem, long, narrow deep green slender leaves and small umbels of white or rose-coloured flower, covered with tiny hairs.

13.2 Chemical structure

Cumin has about 2–4.5% of volatile oil and about 10% fixed oil, together with tannins, oleoresin, mucilage, gum, protein compounds and malates. The characteristic cumin odour is due to the presence of its essential oil. This odour and flavour is due principally to the aldehydes present (i.e, cuminic aldehyde) or cuminol, p-menth-3-en-7-ol and p-mentha 1,3-dien-7-ol). Studies of the chemical composition of cumin oil showed the presence of the following components: α-pinene (0.5%), Myrcene (0.3%), limonene (0.5%), 1-8-cineole (0.2%), p-menth-3-en-7-ol (0.7%), p-mentha-1, 3-dien-7-ol (5.6%), caryophyllene (0.8%), β-bisabolene (0.9%), β-pinene (13.0), P-cymene (8.5%), β-phellandrene (0.3%), D-terpinene (29.5%), cuminic aldehyde (32.4%), cuminyl alcohol

(2.8%), β-farnesene (1.1%) together with much smaller quantities of α-phellandrene, α-terpinene, *cis* and *trans* sabinene, Myrtenol, α-terpineol and phellandral.

13.3 Production

13.3.1 Cumin seed production

Cumin is cultivated extensively as a cold-season crop on the plains and as a summer crop in the hills. In the south part of the Mashad province of Iran it is the main crop with an average production of about 12 000 tons per year. It is cultivated in northern India (the Himalayas, Punjab, Baluchistan, Kashmir) and also in eastern Europe.

For the summer crop the seeds are planted in early April. They should be sown in small pots, filled with light soil, and placed initially in a moderately warm bed to bring the plants on. They can then be hardened gradually in an open frame and transplanted into a warm border of good soil. The plants bloom in June and July, and are harvested when 85% of fruits are ripe. The fresh seeds are spread out on cloth to dry and, after drying, stored in cotton bags.

13.3.2 Cumin oil production

The ripe seeds are used for oil production, both as whole seeds or coarsely ground seeds. If a freely alcohol-soluble oil is required, the whole seed must be used. Hydrodistillation is used for essential oil extraction, producing a colourless or pale-yellow oily liquid with a strong odour. The yield for oil production varies from 2.5 to 4.5%, depending on whether the entire seed or the coarsely ground seed is distilled. Cumin oil can be readily converted artificially into thymol. The volatile oil should be kept in well-sealed bottles or aluminium containers.

13.4 Main uses in food processing

Cumin seed is an ancient spice with a strong aromatic smell and warm, bitterish taste. It is widely used in Iran and India both as a condiment and flavouring in many eastern dishes. In Biblical times cumin seeds were valued for their digestive properties and were used for flavouring bread and other dishes during the periods of ceremonial fasting, to make up for the lack of meat.

Ground cumin can be added, for example, to lime or lemon-based marinades for chicken, turkey, lamb, and pork, or added to chilli, curries or spicy meat stews. It can be added to olive oil when stir-frying vegetables. Whole cumin is used to make various pickles in Iran, Pakistan and India. Cumin is a common flavour in confectionery, meat, sausage and bread manufacturing and as a preservative in food processing.

13.5 Functional properties

Cumin seed and distilled cumin are used as a stimulant, antispasmodic, carminative and antimicrobial agent. They are used as a carminative particularly in veterinary practice. Cumin is used widely in traditional medicine to treat flatulence, digestive disorders, diarrhoea and in the treatment of wounds.

13.6 Quality specifications

13.6.1 Specification for whole seeds

Seeds are oblong in shape, thicker in the middle, compressed laterally, about 3–6 mm long, resembling caraway seeds, but lighter in colour and bristly instead of smooth, almost straight, instead of being curved. They have nine fine ridges, overlapping as many oil channels, or vittae. The odour and taste are somewhat like caraway, but less agreeable. Specific quality indices are:

- seed moisture: less than 6%
- total ash: 7%
- acid insoluble ash: 1.5%
- volatile oil: minimum 2%
- foreign organic matter: 2% (US maximum for harmless foreign matter: 5%)

13.6.2 Powdered seeds specification

The powdered seeds are yellowish-brown with an aromatic, slightly camphoraceous odour and taste. Distinctive characteristics are:

- The epicarp, composed of a layer of colourless cells, polygonal in surface view with thin sinuous walls and a faintly and irregularly striated cuticule; stomata are fairly frequent and, very occasionally, cicatrices may be present. Underlying the epicarps the thin-walled cells of the palisade are sometimes visible.
- The covering trichomes, which are usually found attached to small fragments of the epicarp; they are pluricellular, multiseriate and rounded at the apex, vary in length and are composed of fairly thick-walled cells.
- The sclereids from the mesocarp, of two main types: single layer and elongated cells. They are found frequently associated with the vasculare tissue.
- The fairly numerous pale yellowish-brown fragments of the vittae composed of fairly large, thin-walled cells, polygonal in surface view.

13.6.3 Volatile oil specification

The specific characteristics of cumin oil are:

- colourless or pale yellow
- specific gravity (25º/25ºC), 0.905 to 0.925
- optical rotation (20ºC), + 3 to + 8
- refractive index, 1.501 to 1.506
- solubility (80% ethanol), 8 vol
- aldehydes (as cuminic aldehyde) 40 to 52%.

The physiochemical properties of volatile oils of cumin from various parts of the world are shown in Table 13.1. Cumin essential oil can be adulterated in several ways. One of the most difficult to detect is synthetic cuminaldehyde which cannot be detected easily, though it can affect the optical rotation of the oil. Modern analytical techniques such as stable isotope ratio analysis (SIRA) and selective ion monitoring (SIM) are helpful in detecting adulteration of this kind.

Table 13.1 Physicochemical properties of volatile oils of cumin from different origins

Property	Mediterranean	Mexico	Iran	India	Pakistan
Specific gravity at 15ºC	0.917–0.924	0.936	0.911	0.8945	0.9290
Optical rotation at 15ºC	+4º22′ to +5º6′	+2º55′	+7º	+3.6º	+4.6º
Refractive index at 20º	1.501–1.504	1.507	1.498	1.491	1.501
Aldehyde as cuminaldehyde (%)	47.4–51.50	62.70	32.4	16.00	20.00
Solubility in 80% alcohol (vols required)	5 vols	2 vols and more	6 vols	11 vols	8 vols

13.7 References

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14

Curry leaf

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14.1 Introduction

Curry leaf (*Murraya koenigii* Spreng) (*Syn. Bergera koenigii* Koen (N.O. Aurantiaceae), *Chaleos koenigii* Kurz ex Swingle) is a perennial leaf vegetable. It belongs to the family Rutaceae and is named 'Murraya' after John Adam Murray, Professor of Botany at Gottingen and editor of many of Linnaeus's works. It is a native of the mountainous parts and grows up to an elevation of 1500 m. The curry leaf is found growing throughout India including the Andaman Islands up to an altitude of 1500m.[1] It is recorded wild in Garwhal to Sikkim, Bengal, Assam, the Deccan, Circar mountains, Western ghats, Coromandel and Travancore – Cochin. The leaves of the plant are used extensively for seasoning and flavouring dishes. Curry leaf is exported as curry leaf and as curry leaf oil from India (Table 14.1).

The leaves of the plant are employed extensively as flavourant in curries like 'dal', 'South Indian Sambar', 'rasam' and chutneys and mulligatawny. Ground curry leaf with mature coconut kernel and spices forms an excellent preserve. 'Veppilakkatti', a very famous preparation of South India, can be made with the following ingredients: curry leaf (100 g); tender leaves of malta lemon (50 g); common salt (50 g); seedless tamarind (40 g); red chilli powder without seed (20 g); fenugreek powder (2 g); asafoetida (6 g); black pepper powder (2 g); gingelly oil (10 g). For preparing

Table 14.1 Export of curry leaf from India during 1993–94 to 1997–98 (quantity in tonnes, value in Rs. 1000)

Product	1993–94		1994–95		1995–96		1996–97		1997–98	
	Qty	Value	Qty	Value	Qty	Value	Qty	Value	Qty	Value
Curry leaf	15.2	989.7	10.9	618.8	39.0	1604.4	68.6	2185.1	152.8	3334.2
Curry leaf oil	–	–	–	–	–	–	0.4	115.4	–	–

Source: *Spices Statistics*, IVth edition by Spices Board, Ministry of Commerce, Government of India, Cochin, 682025.

'veppilakkatti', fry the asafoetida in gingelly oil and powder it. Mash the tender leaves of malta lemon in a mixi and remove all the fibres. Then add curry leaves, red chilli powder and other ingredients and grind well. If kept in airtight containers it can be stored for a long time.

14.2 Chemical structure

The leaves contain the following free amino acids: asparagine, glycine, serine, aspartic acid, glutamic acid, theonine, alanine, proline, tyrosine, tryptophan, γ amino butyric acid, phenylalanine, leucine, isoleucine, and traces of ornithine, lysine, arginine and histidine. The leaves also contain a crystalline glucocide, koenigin and a resin.

By analysis of concentrated essence of curry leaf, Macleod and Pieris[2] obtained mainly terpenes. They also found that *M. koenigii* produced less than 4% of other components with eight monoterpene hydrocarbons (Ca 16%) and seventeen sesquiterpene hydrocarbons (Ca 80%). According to them the most important constituents of *M. koenigii* are β-caryophyllene, β-gurjunene, β-elemene, β-phellandrene and β-thujene.

Bhattacharya *et al.*[3] reported a carbazole alkaloid-isomurrayazoline from *M. koenigii* with a structure of 9a,10,11,12,13,13a-hexahydro-5,9,9,12 tetramethyl-1, 12-epoxy-9H-indolo(3,2,1-de) phenanthridine ($C_{23}H_{27}NO_2$). Alkaloids like muconicine, mahanimbine, koenimbine, koenigicine, cyclomahanimbine, mahanimbidine, girinimbine, isomahanimbine, murrayacine, mahanine, koenine, koenigine, koenidine and scopolin were reported by various workers.[4]

From the stem of *M. koenigii,* a new C23-carbazole alkaloid, mahanimbinol, was isolated. It is the key precursor in the biosynthesis of some 20 other carbazole alkaloids. Bhattacharya *et al.*[5] identified two carbazole alkaloids namely 2-methoxy carbazole-3-methyl carboxylate and 1-hydroxy-3-methyl carbazole from the stem bark extract of *M. koenigii*. From the stem bark, alkaloids like mahanimbinol, mukonal, murrayanine, murrayacinine and murrayazolidine were isolated and characterised by various workers.[4]

The fruit is edible. It yields 0.76% of a yellow volatile oil with neroli-like odour and pepper-like taste, accompanied by an agreeable sensation of coolness on the tongue. The characteristics of the oil are as follows:

- specific gravity (13°) 0.872
- refractive index (0°) 1.487
- optical rotation (0°) −27.24
- boiling point 173–174°

The fruit is reported to contain koenigin. A yellow clear and transparent oil is procured from the seeds which is known as limbolee oil.

Chowdhury[6] reported that leaves on hydrodistillation gave 0.5% essential oil on fresh weight basis, having dark yellow colour, spicy odour and pungent clove-like taste. It has the following characteristics:

- specific gravity (25°) 0.9748
- refractive index (25°) 1.5021
- optical rotation (25°) + 4.8[6]
- saponification value 5.2
- saponification value after acetylation 54.6

- acid value 3.8
- soluble in 80% alcohol with slight opalescence

The constituents of the oil are:

- dl-α-phellandrene 4.6%
- d-sabinene 9.2%
- d-α-pinene 5.5%
- dipentene 6.8%
- d-α-terpineol 3.2%
- caryophyllene 26.3%
- isosafrol 4.4%
- cadinene 18.2%
- cadinol 12.8%
- lauric acid 2.7%
- palmitic acid 3.4%

On examination by GC-MS the oil contained aromadendrene, β-bisabolene, butyl myristrate, carvomethone, cis-caryophyllene, β-costol, citral, *trans*-caryophyllene, *iso*-caryophyllene, camphene, dehydro aromadendrene, dipentene, β-elemene, β-eudesmol, farnesol, junipene, linalyl acetate, isomenthone, menthol, spathulenol, stearyl alcohol, ateraldehyde, stearic acid, α-terpineol, palmitic acid, α-pinene and zingiberene.

The essential oils hydrodistilled from leaves of *Murraya koenigii* were analysed by GC and GC-MS. Both essential oils contained mainly monoterpenes and oxygenated monoterpenes. The main constituents are α-pinene (19–19.7%), sabinene (31.8–44.8%), β-pinene (4.2–4.7%), α-terpinene (1.3–4.3%), beta-phellandrene (6.5–7.9%), tauterpinene (3.9–7.1%) and terpinen-4-01 (5.2–9.9%).[7] Madalageri *et al*.[8] reported 21 different compounds in the hydrodistilled essential oil out of which only seven were identified. A commercially important odouriferous compound β-caryophyllene is among them.

14.3 Production

The leaves retain their flavour even after drying and hence these are marketed both in fresh and dried forms. There is not much loss of volatile oil during drying either in sun/shade or in cross flow dryer. Oven drying at 50ºC is recommended as the best technology for conversion of fresh leaves into dry powder.[8] Higher temperatures during drying deteriorated powder quality.

Fresh leaves on steam distillation under pressure (90 lb/in^2) yield 2.6% of a volatile oil (curry leaf oil). According to Madalageri *et al*.[8] hydrodistillation of fresh leaves at 70C is a cheap and non-cumbersome method of extraction of essential oil. Leaf maturity influenced oil composition, the youngest leaves tested being the best. An extended period of extraction caused loss/decrease in certain components while there was gain/increase in other components.

14.4 Functional properties

On analysis the leaves contain the following nutrients:

• moisture	66.3%
• protein	6.1%
• fat (ether extract)	1.0%
• carbohydrate	18.7%
• fibre	6.4%
• mineral matter	4.2%
• calcium	810 mg/100 g of edible portion
• phosphorus	600 mg/100 g of edible portion
• iron	3.1 mg/100 g of edible portion
• carotene (as vitamin A)	12 600 IU/100g
• nicotinic acid	2.3 mg/100g
• vitamin C	4 mg/100 g
• thiamine and riboflavin	absent

The leaves are a fair source of vitamin A. They are also a rich source of calcium, but due to the presence of oxalic acid in high concentration (total oxalates, 1.35%; soluble oxalates, 1.15%), its nutritional availability is affected.

Curry leaf is used in traditional medicine, for example ayurvedic and unani medicine.[9–11] The plant is credited with tonic, stomachic and carminative properties. The undiluted essential oil exhibited strong antibacterial and antifungal activity when tested on microorganisms.[12] Even the crude leaf extracts of curry leaf plant are reported to possess antibacterial activity.[13]

Curry leaf has a potential role in the treatment of diabetes. Hypoglycemic action on carbohydrate metabolism was reported in rats fed with curry leaves.[14] Hepatic glycogen and glycogenesis, as evident from the increased activity of glycogen synthetase, were increased and glycogenolysis and gluconeogenesis were decreased as evident from the decreased activity of glycogen phosphorylase and gluconeogenic enzymes.

Curry leaf is found to exert antioxidant properties in rats fed a high fat diet.[15] There were lower levels of hydroperoxides, conjugated dienes and free fatty acids in the liver and heart of rats supplemented with curry leaves compared to rats fed on the high fat diet alone. Activities of superoxide dismutase, catalase and glutathione transferase were increased in the heart and liver of rats supplemented with curry leaves. Activities of glutathione reductase, glutathione peroxidase and glucose-6-phosphate dehydrogenase were also increased in the liver and the concentration of glutathione was decreased. Thus supplementing a high fat diet with 10% curry leaf can prevent the formation of free radicals and maintain the tissues at normal levels.

Patel and Rajorhia[16] reported that ghee samples treated with 1% curry leaves during clarification showed higher resistance to oxidation and higher sensory scores than those treated with a mixture of BHT (butylated hydroxy toluene) + BHA (butylated hydroxy anisole), due to the presence of naturally-occurring antioxidants. The curry leaves at 1% concentration could be used instead of BHT and BHA for extending the shelf-life of ghee.

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15

Dill

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15.1 Introduction

Dill (*Anethum graveloens* Linn.) is an annual aromatic branched herb known for culinary use since ancient times. It is a native of south-east Europe and is cultivated commercially in most parts of Europe, particularly The Netherlands, Hungary, Germany, Romania, South Russia, Bulgaria and on a lesser scale in France, Sweden, Belgium, Poland, Greece, Spain, UK, Turkey and the United States of America. A variant called east Indian dill or *Sowa (Anethum graveloens* var *sowa* Roxb. ex, Flem.) occurs in India and is cultivated for its foliage as a cold weather crop throughout the Indian sub-continent, Malaysian archipelago and Japan. The earliest reference to use of dill seed in medicine goes back to 'Charak Samhita' (700 BC), an ancient renowned medical treatise on Indian medicinal plants.

Dill foliage, fruits and their volatile oil are used extensively for culinary and medicinal purposes. The fresh aromatic leaves are used in flavouring of soups, sausages, curries, gravies, salad, marinades and pickles; the leafy stems and tops are used in flavouring vinegar, pickled cucumber and fermented cabbages, whereas the seed is used for flavouring meat. In Malaysia and Indonesia, the leaves are steamed with rice whereas fruits are used in flavouring native confectionery. Balkan countries use dill in flavouring yogurt, sour cream and wine. In Sweden, bread is flavoured with dill seed. Dill fruit faintly resembles caraway in odour but has a less sharp taste. It is a popular condiment in Asian countries and is used in seasoning several types of processed meat. The leaf oil has largely replaced the use of the fresh herb in the food industry in Europe.

The International Trade Centre (Anon. 1991) has brought out a material survey of four west European countries (France, UK, The Netherlands and Germany) estimating an overall demand of freeze-dry herb to be less than 300 tonnes per annum. France produces a small quantity and imports it from Egypt, Israel, The Netherlands and Morocco. The Netherlands and Germany are larger producers and import a part of their demand from Hungary. The USA is said to import between 70 and 100 kg of herb oil annually, largely from Hungary. India exports 500 to 800 tonnes of seed annually to west Asian countries

and a small quantity of dill seed oil to western Europe. Varshney (2000) has reported world production of dill weed oil as 80 tonnes and that of dill seed oil as 70 tonnes; the seed oil is produced mainly in India, Russia and Poland.

Dill is characterized by long dissected leaves and compound radiating umbels. It grows to between 1 and 1.2 m in height under cultivation. Dill is an annual glabrous, long-day plant with long fusiform (10–15 cm) tap root with few secondary rootlets. The stem is erect, dull-green, glaucous, cylindrical, fistular with longitudinal light-green streaks, up to 1.5 cm thick around the base. It is subdichotomously branched, usually above the basal few nodes. Leaves are decompound, tripinnati-partite with ultimate segment 5–15 (−20) mm long and 1–1.5 mm wide. Flowers are small, bisexual, more in outer unbellules (30–40) than inner ones (15–20), and opens centripetally. The fruit is oblong, slightly plano-convex in shape, dorsally compressed, 3–4 mm long and 1.5–3.0 mm broad, glabrous, with three prominent longitudinal ridges, developed into thin broad wings, 0.25–0.5 mm wide. Dill flowers in June–August and fruiting takes place in August–October in Europe, while it is February–March and March–April respectively in India.

In the Sowa plant, the fruits are longer, 3–5(−5.5) × 1.5–2.5 (−3) mm in dimension, with three longitudinal ridges on the dorsal side more pronounced than the (European) dill. The carpophore holds two mericarps more firmly and consequently these remain joined together in the fruit for a longer time. The vittae has irregular marginal walls in contrast to straight walls in the dill. It has a number of local races like *Vizak Sowa*, *Variyali Sowa* and *Ghoda Sowa* distinguished by the oil composition of their fruits (Shah and Quadri, 1994; Randhawa and Kaur, 1995).

15.2 Production

Dill is grown as an irrigated annual crop both in temperate and tropical regions up to 1000 m (m.s.l.). The crop remains in the field for 125 to 180 days. In India, sowing is staggered at a fortnight's interval (Oct–mid-December) to obtain fresh foliage crop, marketed throughout the winter season. A large number of varieties are known in cultivation (Randhawa and Kaur, 1995). Dill prefers light sandy to loamy well drained fertile soils, slightly acidic to neutral in reaction; the pH extends to 8.5 in sub-tropical parts of India. It prefers warm sunny weather, particularly cool moist climate favours vegetative growth and warm, drier and sunny conditions are needed for luxuriant flowering and fruiting to ensure a high crop yield.

The seed is sown directly during the spring season (February–March) in temperate climate and October in tropical conditions. Seed rate is 5 to 10 kg per hectare depending on the method of sowing, viz. drilling in rows or broadcast; usually it is sown in rows, 1.5 to 2.0 cm deep at 30 to 60 cm apart and spacing at 45 × 20 cm is found to produce high seed yield in India (Gupta, 1976). Germination commences after a week in tropical regions and may take two weeks in warm temperate conditions. Pre-emergence application of herbicide like Prometryne (50%) at 1.0 kg per hectare is recommended (Timoshenko, 1970). The plants are thinned when 7 to 10 cm tall at 15 to 20 cm apart in the rows. The crop remains 40 to 67 days in vegetative stage (after germination) and flowering/fruiting continues for the next 85 to 90 days. Powdery mildew (*Erysiphae* spp.) sometimes attack the crop at flowering, occasionally causing severe damage for which spraying of Bordeaux mixture three to four times at weekly intervals is recommended. Similarly, aphids (*Myzus* spp) suck flowering axils causing loss in growth vigour and weekly spraying of Melathione (0.2%) in water controls the infestation.

The crop responds favourably to use of inorganic fertilizers depending on the nutrient status of the soil. Atanasov *et al*. (1976) observed that application of 70 kg per hectare each of N, P_2O_5 and K_2O produced maximum herbage yield and most economic oil yield in Bulgaria. In India where soils are rich in potash, 60 kg of N and 45 kg of P_2O_5 per hectare produced maximum seed yield (Gupta, 1982). Usually, five to eight light irrigations are given to the seed crop. Two rounds of weeding cum hoeing given between 30 and 40 days and 60 and 70 days suffice to control weeds; later growth of the crop covers the field and smothers weeds.

The herb oil is a colourless to brownish-yellow mobile liquid. The fresh herb at vegetative stage contains 0.60% of oil, which progressively increases with growth and is 0.78–0.99% at flowering, rises to 1.28–1.91% at milky-wax seed ripening and 1.9–2.84% in the herb when the seed is nearing maturity. For herb oil, the crop is harvested when it is between maximum flowering to beginning of fruit formation stage as oil content in the leaves is high and the oil has a lower amount of oxygenated compounds. In Germany and The Netherlands, the entire over-ground crop is harvested at blooming stage (with no seeds) whereas milky-wax to mid-ripe fruiting stage is preferred for obtaining herb oil (dill weed oil) in Hungary and USA. As a matter of fact, the relative quantity of fruits present in the harvested material and their state of ripening determine the oil content and flavour of the oil produced on distillation. On average 2.5 to 3.0 tonnes of fresh herb per hectare is produced when the crop is harvested at maximum flowering stage, which on distillation give 18 to 20 kg of herb oil, containing up to 30% carvone. Harvesting at later stages increased oil yield and its carvone content progressively.

In the seed crop, the terminal umbels are hand-picked when the fruit begins to turn yellowish-brown in colour; these come to maturity 40 days early. The rest of the crop is cut from the base later when tertiary umbels begin to turn brownish; delay may cause seed shattering leading to crop loss. The harvested crop is transported to the threshing floor where it is dried in a thin layer for one or two days before carrying out light threshing to separate the fruits. It is found that the milky-waxy fruit maturity stage contains maximum seed oil (Zlatev, 1976); the carvone and dihydrocarvone contents accumulated rapidly in the later part of fruit maturity. The seed yield ranges from 700 to 800 kg per hectare and shade dried seed contains 3–4% oil; the seed yield in east Indian dill (Sowa) is higher (1 tonne per hectare).

The wilted dried plants show a decrease in carvone content over the fresh herb at every stage of growth until flowering, but this trend is reversed in fruiting herb as wilted, dried and stored material showed an increase in carvone content in the oil. As a matter of fact, the dried herb produces oil emitting poor intensity of odour. The mature stored seeds yield a higher quantity of carvone because some of the terpines in the seed are lost during storage; this could be protected by storing seed in gunny bags, lined with polythene in a dry cool place.

The essential oil of herb as well as seed crop is obtained through hydrodistillation or steam distillation and complete exhaustion of the produce takes 4.0 and 2.5 hours respectively for herb crop and 8 to 10 hours for seed crop; the seed are crushed into powder to facilitate easy extraction of the oil. During the first one or two hours, the distilled oil has high d-carvone content and the broad ratio between carvone and limoanene is 80(88) : 12(19); because carvone is more easily soluble in water and being higher boiling fraction, it is distilled easily. This trend declines at a later stage. The wilted (herb) material should be distilled within 72 hours.

15.3 Chemical composition

Lawrence (1980) analysed dill herb using IR as a method of characterization of individual constituents by preperative GC and column chromatographic fractions. He reported the oil to contain α-pinene (0.9%), β-pinene (0.1%), myrcene (0.4%), α-phellandrene (30.2%), limonene (22.5%), β-phellandrene (3.8%), p-cymene (1.0%), terpinolene (0.1%), α-p-dimenthylstyrene (0.1%), 3,9-epoxy-p-menthlene (5.6%), *cis*-p-mentha-2,8-dien-lol (0.1%), transdihydrocarvone (0.5%), *cis*-dihydrocarvone (1.2%), carvone (31.6%), di-hydrocarveol (0.1%), *cis*-carvyl acetate (0.1%), *trans*-carveol (0.1%), *cis*-carvyl acetate (0.1%), *trans*-carveol (0.1%), dihydrolimonene-10-ol (0.1%), dihydrolimenon e10-yhexanoate (0.1%), p-mentha-l, 3-dien-10-yl-hexanoate (0.1%) and p-mentha-1(7), 2-dien-10-yl butyrate (0.1%) besides a host of other compounds in traces.

Lawrence (1981) has reproduced chemical composition of seed oil obtained through solvent extraction by Kodam at Leiden University (doctorate dissertation). It was found to contain limonene (44.0%), d-p, dimethylstyrene (0.2%), transhydrocarvone (0.4%), cis-dihydrocarvone (2.1%), neodihydrocarveol (0.2%), carvone (51.5%), dihydrocarveol (0.1%), isodihydrocarveol (0.4%), trananethole (0.1%), trancarveol (0.1%) and *cis*-carveol (0.2%) besides many other compounds in traces. An interesting feature of growing dill is that after successive generations, the European dill develops higher oxygenated compounds in the oil, which includes a small quantity of dillapiole. It was found to contain up to 3.0% of dillapiole (Baslas *et al.,* 1971) when grown under tropical climate. Gupta (1982) explained this as being due to more sunlight hours combined with solar intensity in the tropics.

15.4 Compounds influencing flavour

The principal constituents of the herb oil are phellandrene and limonene whereas ketone (calc. as carvone) in the oil increases from 12% (vegetative stage) to 22% (maximum bloom) and rises to 35% at the milky-wax stage, when its herb character predominates. In trade, the oils containing 20% or less carvone have been found to be of finest flavour (Guenther, 1950). The herb oil has a powerful sweet-spicy, peppery and aromatic odour, reminiscent of spearmint oil with a sweet nutmeg-like undertone. The taste is warm and slightly burning, but pleasant and not pungent.

For flavouring purposes, the herb oil with low ketones (carvone) is preferred. The typical flavour of the oil is due to α-phellandrene (terpine) as the oil resembles the fresh herb in aroma. Haupalehti (1986) determined that α-phellandrene, limonene, myrsticin and dill furan were the most significant contributors of dill herb aroma. Later, Blank *et al*. (1991) determined that the aroma of dill herb was directly related to concentration of five components namely dill-furan, α-phellandrene, limonene, myrsticin and p-mentha dienbutyrate.

The seed oil is very mobile, light yellow to pale-yellow in colour, becoming dark on ageing; and its taste is less sharp than caraway oil. Its aroma is warm and spicy, slightly burning but pleasant and powerfully aromatic sweet. The oil contains large quantities of carvone (40–60%) which is its principal flavour constituent. There is no difference in odour value between dill and Sowa seed oils. The aroma of dill seed oil was characterized by carvone but 4-vinyl-2-methoxyphenol (which gives it a spicy meat-like note), 4-hydroxy-3-methyl-6(l-methylethyl) cyclohexenlone (responsible for dill like sweet note) and dill furan contribute to its characteristic flavour.

15.5 Functional properties and toxicity

The leaves are rich in minerals, mainly calcium, phosphorous and iron; they contain nine amino acids as well as flavanoids. However, both these oils have anti-bacterial property and are known to protect prepared food from contamination during storage.

In traditional medicine dill fruit has carminative, aromatic stimulant, stomachic and diuretic properties. The emulsion of seed oil in water (dill water) is useful in relieving flatulence, colic pain, vomiting and is a household remedy to correct gastric disorders in children. The dill fruit contains petroselinic acid triglyceride, β-sitosterol, glucoside, coumarins and flavanoids as well as large quantities of fats and proteins. It is also used in veterinary medicine.

The oil of east Indian dill (Sowa) has an additional component called dillapiole ($C_{12}H_{14}O_4$, molecular weight 222.23) in high proportion (20%) and, compared to dill, has lower carvone content (30–45%). The dillapiole is toxic when taken in large doses. But being heavier than water with high boiling point (285ºC), it is easily separated through fractional distillation. The oil free of dillapiole approaches physical constants of European dill (seed) oil (Shah *et al*., 1972) and being a cheaper source, is employed in production of gripe water. The dillapiole is a viscid colourless substance and is found to have a synergic action on pyrethrins (used in insecticides), making it more effective over synthetic synergics like piperonyl butaoxide.

15.6 Quality indices and standards

The presence of a minimum of 5.0% 3,9,epoxy-p-menthene in dill herb oil is a good indicator of its purity. There is no commercial source of this compound available to enable reconstitution of the oil. Lawrence (1981) has opined that examination of the percentage ratio of, α-phellandrene to limonene to β-phellandrene is another test for quality determination; the acceptable ratio was found to be 20:25:3 in dill herb oil.

Dill herb oil is easily differentiated from caraway oil as carvone content in the latter ranges from 47.3% to 59.5%, while in dill oil it is 27.2 to 53.3%. Further, the α-pinene and α-phellandrene in the caraway oil is very meagre (traces to 0.1%) whereas these are between 0.1 to 0.2% and 1.0–2.3% respectively in dill herb oil.

The east Indian dill seed (Sowa) oil contains large quantity of dillapiole (20%) and the oil has three flavanoids, viz. quercetin, kaempterol and isorhamnetin, which produce distinct spots on TLC (Shah and Quadri, 1994). The presence of high carvecrol is usually an indicator of an aged, partially oxydised, seed oil. The LD_{50} of dill seed oil is 300 mg per kg body weight (tested on mice).

According to the British Pharmaceutical Codex (Anon. 1963), the dill fruits should contain not less than 2.5% (volume by weight) of volatile oil and not more than 3.0% of acid soluble ash. The commercial powdered dill should be ground fine enough to pass through a mesh of 54 screen. It should contain not less than 43.0% (w/w) and not more than 63% (w/w) of carvone.

The physical constants of dill are (Anon., 1964):

- specific gravity (25ºC) 0.890–0.915 (temp. correction factor 0.00056 per ºC)
- optical rotation +70º to +82º
- refractive index (20ºC) 1.4830º–1.490º
- carvone content 42 to 60 (by neutral sulphide method)
- soluble in two or more volumes of 80% alcohol (occasionally) with slight opalescence.

As a rule, organoleptic evaluation of the oil can easily identify variations introduced through addition or substitution of any flavour compounds in the oil. The specification of oil of east Indian dill seed (Sowa) is (Anon. 1992):

- specific gravity (27ºC) 0.9360–0.9800
- optical rotation +50º to 65º
- refractive index (20ºC) 1.426–1.495
- ester value before acetylation 35–42
- ester value after acelylation 50 to 65
- total ketone (calc. as carvones) min. 35%
- soluble in 0.5 and more vols of 90% alcohol.

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16

Garlic

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16.1 Introduction

Garlic (*Allium sativum* L.) is the second most widely cultivated Allium after onion. According to FAO estimates for the year 1999, the world area cultivated is 889,000 ha and production is 8,776,000 mt. China, Korea, India, USA, Spain, Argentina and Egypt are the major garlic growing countries. China ranks first in area (424,000 ha) and production (5,690,000 mt) followed by India in area (113,000 ha) and Korea in production (484,000 mt) (Table 16.1). In productivity, Egypt tops the list (25,366 kg/ha) followed by USA (16,250 kg/ha), China (13,421 kg/ha) and Korea Republic (11,916 kg/ha). Korea Republic has the highest per capita availability, i.e. 10.50 kg per year followed by Argentina (5.01 kg) and China (4.53 kg). The world garlic area, production and productivity trends during the past decade show that since 1986 they have improved by about 115.78%, 245.92% and 60.41%, respectively (Table 16.2). Garlic is in demand almost all the year round all over the world both in fresh form and also in dehydrated form. Today, garlic is used for its flavour, aroma and taste being prepared domestically or forming a raw material for a variety of food manufacturing processes (dehydration and pickling).

Fresh garlic is widely used in cooking. In India and other Asian and Middle East countries, it is used in pickles, curry powder, curried vegetables, meat preparation, tomato ketchup. In the Philippines, Central Eastern Asia and in parts of the tropics, the green tops as well as bulbs of garlic are used. Dehydrated garlic in powdered or granulated form has replaced the use of fresh bulbs for industrial and home use in many countries. Dehydrated products of garlic are common as a condiment and in the food industry. It is reported that in America about 50% of the total production of garlic is dehydrated and sent to food processors.

Garlic is a frost-hardy bulbous perennial erect herb of 30–100 cm in height with narrow flat leaves and bears small white flowers and bulbils (Janick, 1979). It is a herbaceous annual for bulb and a biennial for seed production. The shape of garlic is smooth, round and solid for its entire length unlike onion which is hollow. Many cloves of garlic do not produce flowerstalks. The inflorescence may be partially or not at all

Table 16.1 Area, production, productivity and per capita availability of garlic in different countries during 1999

Country	Area ('000 ha)	Production ('000 mt)	Productivity (kg/ha)	Per capita availability (kg/year)
Africa	**17**	**178**	**10311**	
Algeria	8	30	3750	1.00
Egypt	5	114	25366	1.73
Morocco	2	7	3829	0.26
N.C. America	**25**	**301**	**12218**	
Mexico	9	65	7647	0.68
USA	14	224	16250	0.82
South America				
Argentina	15	181	11727	5.01
Brazil	11	63	5563	0.38
Peru	5	30	5883	1.21
Asia	**682**	**7280**	**10667**	
China	424	5690	13421	4.53
India	113	452	3996	0.46
Indonesia	11	38	3599	0.18
Korea Rep.	41	484	11916	10.50
Turkey	14	106	7571	1.64
Myanmar	14	53	3782	1.19
Bangladesh	13	40	3022	0.32
Thailand	21	131	6235	2.17
Europe	**125**	**699**	**5594**	
Italy	4	34	8550	0.59
France	6	45	7759	0.77
Yugoslavia	12	44	3631	4.14
Russian Fed.	25	161	6381	1.09
Romania	12	58	4833	2.58
Spain	25	170	6827	4.29
Ukraine	21	79	3762	1.55
Oceania	**–**	**1**	**7143**	
New Zealand	–	1	7143	0.26
World	**889**	**8776**	**9875**	**1.49**

Source: FAO Quarterly Bulletin of Statistics (3/4) 1999.

exerted, its bulbils forming a swelling somewhere within the false stem a few cm above the bulbs. The bulb consists of 6–35 smaller bulblets called cloves and is surrounded by a thin white or pinkish papery sheath (Bose and Som, 1986).

Alliums have been cultivated for thousands of years for therapeutic and prophylactic properties, religious significance, and flavour and taste. The Chinese,

Table 16.2 Trend of area, production and productivity of garlic in the world

	World		
	1986	1999	Increase (%)
Area (million ha)	0.41	0.89	115.78
Production (million ton)	2.54	8.78	245.92
Productivity (ton/ha)	6.16	9.88	60.41

Sources: FAO Quarterly Bulletin of Statistics (3/4) 1999 and FAO Production Year Book 1988.

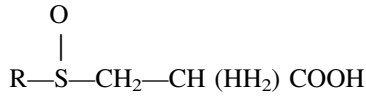
Sumerians, Indians and Ancient Egyptians are all known to have consumed garlic over 4000 years ago. Among others, Hippocrates (430 BC) and Theophras Tuso (322 BC) have described the consumption of garlic in the Greek and Roman period (Rabinowitch and Brewster, 1990). Garlic is thought to have originally come from Central Asia and Southern Europe, especially the Mediterranean region (Thompson and Kelly, 1957). Some authorities consider that *Allium longicuspis* Regel, which is endemic to Central Asia, is the wild ancestor and spread in ancient times to the Mediterranean region.

Garlic presents an interesting problem of classification and quality given the wide range of cultivars, differing in maturity, bulb size, clove size and number, scale colour, bolting, number and size of inflorescence bulbils and presence or absence of flowers (Bose and Som, 1986). Taxonomists have recognised at least four botanical varieties within *Allium sativum L.*, namely *A. sativum L.*, Var *sativum*, *A.sativum L.* Var., Ophioscorodon (Link) Doll, *A. sativum L.* Var Pekinense (Prokh) Maekawa and *A. sativum L.* Var nipponicum Kitamura. Jones and Mann (1963) could not satisfactorily classify many garlic cultivars into clearly defined botanical varieties, because many show combinations of characteristics from two or more varietal groups. It appears, then, that the above botanical classification has little advantage. Following criteria may be of practical use for distinguishing different garlic cultivars (Rabinowitch and Brewster, 1990):

- *Morphological characteristics such as:* Bolting type, number and size of cloves, number of leaf axils, forming cloves, number of secondary cloves formed in a lateral bud, bulb weight, colour of the outer protective leaf of the cloves, number of protective leaves, width and length of foliage, plant height and tenderness of the green leaves.
- *Physiological and ecological characteristics:* Time of bulbing and maturity, low temperature and long day requirements for bulb formation, winter hardiness and bulb dormancy.

16.2 Chemical structure

Garlic or any other Allium is characterised by the remarkable sulphur-containing compound present in it which gives distinctive smell and pungency. Uninjured bulb of garlic contains a colourless, odourless water soluble amino acid 'Alliin' which includes the presence of the volatile flavour compounds. These precursors are of the general name S-alk(en)yl cysteine sulphoxide. The general structure of the flavour precursor is:

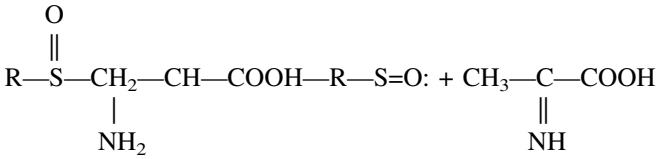


The group to the right of R moiety is the –L-cysteine sulphoxide group. The group R can be:

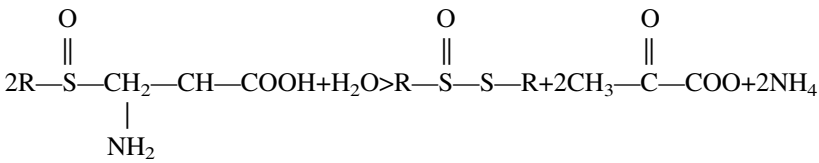
1. CH_3— -called (+)-S-methyl
2. CH_3—CH_2—CH_2— -called (+)-S-propyl
3. CH_3—CH=CH— -called trans (+)-S-(1-propenyl)
4. CH_2=CH—CH— -called (+)-S-(2-propenyl)

When the fresh tissue is damaged, the flavour precursors react under the control of the enzyme alliinase (S-alk(en)yl-L-cysteine sulphoxide Lyase) to release the highly reactive sulphenic acids plus ammonia and pyruvate. Alliin, or S-allyl cysteine sulphoxide, was the first sulphur compound isolated from *Allium sativum* (garlic). The enzyme alliinase is confined to the cell vacuole, whereas the flavour precursors are confined to the cycloplasm probably within small vesicles associated with their presence in the cell. Hence the enzyme has access to the precursors only when cells are disrupted. In garlic, alliinase catalyses the formation of allicin, which gives fresh garlic its characteristic smell (Brewster, 1994).

Alliinase (E.C.4.4.1.4., S-alk(en)yl-L-cysteine sulphoxide cyase is the enzyme ultimately responsible for the development of the flavour compounds. The reaction catalysed by the enzyme is a beta elimination of the S-alk(en)yl sulphoxide group from the substrate:



Both products of the reaction are chemically unstable; the Ketimore product spontaneously hydrolyses to pyruvate and ammonia while the reactive sulphur species will combine with any of a number of co-reactants, most often another of the same species, to give a range of flavour components. Thus the reaction is commonly described as:



Rabinowitch and Brewster (1990) have elaborated the details about the alliinase solubility and stability, purification, physical, chemical and catalytic properties. They report that alliinase from Alliums is less soluble. It is difficult to maintain this enzyme in aqueous solution. A cosolvent is required to maintain the enzyme activity. It is further reported that alliinase enzyme has a tendency to aggregate and precipitate and gets totally inactivated by freezing.

Alliinase from garlic was first prepared by Stoll and Seebeck in 1947; however, the preparation was relatively crude. A common feature of the preparation is the use of a polyalcohol cosolvent, 10% glycerol in the case of garlic enzyme. The purification of garlic enzyme also required the presence of 10μM pyridoxal phosphate in the buffers. The garlic enzyme has been described as having a molecular weight of 130,000 with two subunits of 65,000. Spectral studies on alliinase from garlic revealed an absorption peak at 420 nm characteristic of pyridoxal phosphate. Garlic alliinase has been reported to contain no carbohydrate. However, the presence of a subunit band giving a periodic acid–schiff base stain on SDS gels of the purified enzyme indicates that the enzyme is a glycoprotein.

The general catalytic properties of alliinase were well described long before the enzyme was purified to homogeneity. A broad pH optimum of 5–8 was described by Stoll and Seebeck (1947) for the garlic enzyme with a temperature optimum under the

condition of assay of 37C. They also made observations on the specification of the reaction: the substrate must be a derivative of (-)L-cysteine, the sulphur atom must be linked to an aliphatic group, the amino group of cysteine must not be substituted and the sulphur atom must be in the sulphoxide form with the + and − configurations both being substrate.

16.3 Processing

Raw garlic no doubt has the ideal flavour and provides desirable textural and water retaining properties when incorporated into food products, bulk of raw garlic is water and lacks flavour and aroma. Also handling and storage costs are more when garlic is used in raw form. Dehydration or flavour extraction reduces the quantity which ultimately lowers the transportation and storage costs. Processing, however, may introduce undesirable changes in appearance. It may also modify the natural balanced aroma and flavour.

Many modern automated food processing plants are not able to handle the raw form of garlic as such a range of garlic products are available to meet the particular needs of the market. Garlic flakes, garlic powder, garlic oil and garlic juice are some of the processed forms of garlic which are widely used by the food industry. Garlic capsules and tablets are also prepared and these products have a ready market in view of their high medicinal values.

16.3.1 Garlic dehydration

A schematic representation of the process for garlic dehydration is shown in Fig. 16.1. The garlic bulb is broken into individual cloves by passing between rubber covered rolls which exert throughpressure to crack the bulb without crushing the cloves. The loose paper shell is removed by screening and aspirating. The cloves are then washed in a flood washer. At this stage the root stubs are floated off. Slicing is then done on a specially designed high-speed cutter. The sliced garlic cloves are then spread on drying trays which in turn are stacked on transfer cans. Tunnel type dehydrators are used for dehydration. The cans are placed in these tunnels and hot air is blown across the trays. The sliced garlic cloves are dried down to about 10% moisture in this operation which takes about 10–15 hours at 60–65ºC. It is, however, preferable to keep the temperature below 57ºC while drying (Pandey, 1997).

Part of the remaining moisture is usually removed in a finishing operation for which garlic cloves are placed in large bins. Warm air is forced upward through the bins. This bin drying and conditioning operation may take about 30 hours. In these drying operations temperature must be controlled so that browning or scorching do not occur. After the slices are dried, they may be screened for removal of large partially dried slabs and fines. The fines may account for one third of the total dehydrated product. Usually fines are ground into powder. The slabs may be broken up and redried. The slices are prepared in the form of flakes. Grinding and packaging of powder is done in low humidity surroundings to avoid gumming and caking. Garlic is commercially dried to 6.5% moisture.

It is reported that dehydrated garlic is available in six forms: powdered, minced, coarse, granulated, chopped and diced. It is generally considered that about 5 kg fresh garlic bulbs from the field make 1 kg of dried product. On the basis of chemical, microbial and sensory studies, it is also reported that 60ºC is the maximum temperature

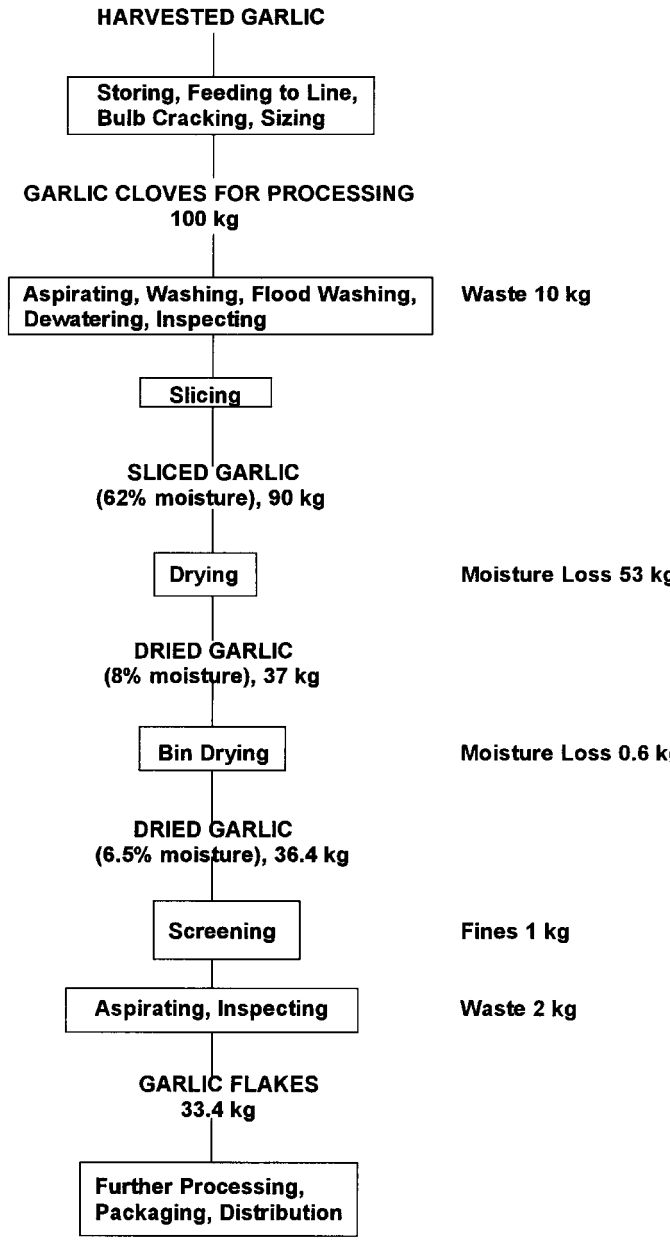


Fig. 16.1 A schematic representation of the process for garlic dehydration. (From Van Arsdel *et al.*, 1973).

for dehydration of garlic. Hot air drying technique is considered to be the most economical. Storage of garlic powder was best achieved in cans, the use of sealed polyethylene bags being considered unsatisfactory. Odourless garlic powders as health supplements may be produced by inactivating alliinase by contacting garlic with fumaric acid/fumarate or by physically separating garlic powder and alliinase. Freeze drying of the garlic/cyclodextrin (70:30) mixture has also been claimed to produce an odourless product. Dehydrated garlic is prone to discoloration. Darkening is associated with non-

enzymic Maillard reactions and may be prevented by reducing temperature. A green discoloration associated with the maceration of garlic tissue may be minimised if dormant tissue is processed (Rabinowitch and Brewster, 1990).

There are reports that there is adverse effect of processing on quality and intensity of flavour. Dehydration has been associated with loss of more than 90% of the flavour intensity (Pruthi, 1980). This represents both a potential environmental problem and a significant economic loss. The origins of such losses has been examined and it has been concluded that they occur prior to the realisation of a critical moisture content, wherefrom the flavour may be envisaged as being sealed within the product (Mazza and Le Maguer, 1979).

16.3.2 Garlic oils

Volatile oils comprise 0.1 to 0.25% of the fresh weight of garlic. Garlic oil is recovered by steam distillation of freshly ground cloves. It is a reddish brown overpowering liquid. One gram of oil is equivalent in flavouring terms to 900 g fresh garlic or 200 g dehydrated garlic powder. The high pungency of garlic oil makes it difficult to use directly. The oil is commonly diluted in vegetable oil. It is being used in ice-cream, ices, confectionery, baked goods, chewing gum and condiments. The rates of 6 ppm in baked products, 0.01–0.3 ppm in beverages, 16 ppm in condiments, 12 ppm in chewing gums, 12.9 ppm in confectionery and 40 ppm in ice-cream are being used.

16.3.3 Other products

Garlic is also processed in the form of garlic juice and garlic salt. Garlic oleoresin is a dark viscous liquid, having 12 times the flavour of dehydrated garlic or 50 times that of fresh garlic cloves. Garlic paste is formulated from suitable flavours and viscous edible base.

Garlic salt is comprised of a free flowing, uniformly blended dry mixture of non-iodised salt, the approximate composition of which is shown in Table 16.3. Garlic salt should not contain more than 2.5% moisture, more than 81% salt and should have moisture-free white garlic powder between 18–19%, and 1–2% calcium stearate. Garlic

Table 16.3 Approximate composition (100 g) of garlic salt

	Garlic salt
Water	1.4 g
Energy	63 kcal
Protein	3.2 g
Fat	0.1 g
Carbohydrate	13.8 g
Fibre	0.4 g
Ash	81.5 g
Ca	220 mg
Fe	1 mg
Mg	11 mg
P	79 mg
K	212 mg
Na	31.4 g
Zn	1 mg
Vitamins	–

salt has much wider culinary potential than powder and one tablespoon is equivalent to a clove of fresh garlic.

16.4 Uses

Garlic is used practically all over the world for flavouring various dishes. In America about 50% of the entire output of fresh garlic is dehydrated and sold to food processors for use in mayonnaise products, salad dressings, tomato products and in several meat preparations. Raw garlic is used in preparation of garlic powder, garlic salt, garlic vinegar, garlic cheese croutons, potato chips, garlic bread, garlicked meat tit-bits and garlicked bacon, etc., which have been boosted in the American market. Spray-dried garlic products including garlic preparations are also available in the market. In Italy, Europe and Latin America, the spectacular popularity of garlic is shown by the methods by which it is boosted by the garlic growers. In India and other Asian and Middle East countries, garlic is already being used in several food preparations notably in pickles, curry powders, curried vegetables, meat preparations and tomato ketchup, etc. There has been increasing demand for garlic by the food industries for garlic powder as a condiment. Oil of garlic has now been appreciated as a valuable flavouring agent, for use in all kinds of meat preparations, soups, canned foods and sauces (Pruthi, 1987).

16.5 Functional properties and toxicity

Garlic has been considered as a rich source of carbohydrate, proteins and phosphorus. Ascorbic acid content was reported to be very high in green garlic (Prodan *et al.*, 1977). The nutritive composition of fresh and peeled garlic cloves and dehydrated garlic powder as reported by Pruthi (1987) is given in Table 16.4.

Studies suggest that garlic, which contains more than 200 different compounds, has biological activities that can have medically important effects. Garlic has been used as an excellent carminative, a nerve tonic and an antiseptic agent in Hindu medicine for centuries (Aman, 1969). However, it has been only recently that its medical benefits have been explored in detail. The functional properties of garlic have been reviewed by Agarwal (1996), Koch and Lawson (1996) and Lawson (1998a). These properties include the following:

- cholesterol lowering properties reported by numerous studies (including Reuter and Sendl, 1994; Han *et al.*, 1995; Adler and Holub, 1997). These studies have reported an average 10% reduction in total serum cholesterol. Evidence suggests that these effects are due to allicin or allicin-derived compounds (Yeh and Yeh, 1994; Gebhardt and Beck, 1996). Some recent studies, however, have produced contradictory results (Berthold and Sudhop, 1998), though this may be due to the composition of the garlic supplements studied (Lawson, 1998b)
- garlic significantly lowers blood pressure (Silagy and Neil, 1994; Das *et al.*, 1995a and 1995b)
- garlic has an influence on platelet aggregation, an important factor in cardiovascular disease (Lawson *et al.*, 1992; Han *et al.*, 1995; Batirel *et al.*, 1996). It also has an effect on blood coagulation and fibrinolytic activity which are factors in the development of thrombosis (Han *et al.*, 1995; Breithaupt-Grogler *et al.*, 1997)

Table 16.4 Nutritive composition of fresh/peeled garlic cloves and garlic powder (Pruthi, 1987)

Nutrients	Fresh peeled garlic cloves	Garlic powder
1. Moisture (%)	62.8	5.2
2. Protein (%)	6.3	17.5
3. Fat (%)	0.1	0.6
4. Mineral matter (%)	1.0	3.2
5. Fibre (%)	0.8	1.9
6. Carbohydrates (%)	29.0	71.4
7. Calcium (%)	0.03	0.1
8. Phosphorus (%)	0.31	0.42
9. Iron (%)	0.001	0.004
10. Sodium (%)	–	0.01
11. Potassium (%)	–	1.1
12. Niacin (%)	–	0.7
13. Vitamin-A	0	17510/100 g
14. Vitamin-B (mg/100 g)	0	0.68
15. Vitamin-B_2 (mg/100 g)	0	0.08
16. Vitamin-C (mg/100)	13.00	12.00
17. Nicotinic acid (mg/100 g)	0.4	
18. Caloric value (food energy)	142 calories/100 g	380 calories/100 g

- epidemiological studies have suggested a link between garlic consumption and a reduced risk of stomach cancer (Steinmetz *et al.*, 1994; Han *et al.*, 1995; Milner, 1996). Various constituents of garlic have been identified as inhibiting tumour growth, notably garlic-derived organosulphides (Srivastava *et al.*, 1997; Pinto *et al.*, 1997; Riggs *et al.*, 1997; Hu and Singh, 1997; Sakamoto *et al.*, 1997).
- Garlic also has antioxidant properties which are helpful in preventing cancer and cardiovascular disease (Horie *et al.*, 1992; Phelps and Harris, 1993; Imai *et al.*, 1994).
- garlic has antibiotic properties and has been used to treat wounds when other antibiotics were not available (Fenwick and Hanley, 1985a; Han *et al.*, 1995).

Although anticarcinogenic activity of garlic has been well documented (Lau *et al.*, 1990), the mechanism by which garlic compounds prevent carcinogenisis of many chemicals is not entirely clear. One possible mechanism is the ability of sulphur-containing garlic compounds to block the activation of procarcinogens to carcinogens by hepatic mixed function oxidases. It is interesting to note that diallyl sulphide has been found to inhibit hepatic mixed function oxidases at high doses (Dalvi and Salunkhe, 1993). Garlic is also effective against gastric cancer.

16.5.1 Toxicity of garlic

Since the consumption and level of sulphur-containing ingredients of garlic that are supposed to be toxic are so low, acute or fatal garlic poisoning in humans is very rare. A case report on wild garlic poisoning in sheep indicates that the poisoned animals showed hemolytic anemia, jaundice, very dark discoloration of the kidneys and hemoglobinuria (Stevens, 1984). Histopathological examination of the dead animals showed a marked tubular necrosis and hemoglobin casts in the kidneys and centrilobular necrosis of the liver. These toxic effects were attributed to a high level of S-methylcystein sulphoxide, a sulphur-containing amino acid which is a precursor of hemolytic anemia factor dimethyl

disulphide found in garlic. Compounds such as di(prop-2-enyl) disulphide present in garlic have been found to cause contact dermatitis (Mitchell, 1980; Hjorth and Roed-Peterson, 1976) and may also be responsible for occupational allergy.

The mechanism of toxic action of sulphur-containing compounds of garlic, especially allicin, has been reported to lie in their ability to react with –SH groups of enzymes and properties. Therefore, though garlic has many medicinal properties, it has serious toxic effects, if taken in large quantities for medicinal uses, which may present as anemia, stomach ulcers, severe allergic reaction and suppression of testicular functions. Further studies on safety of garlic are thus needed.

16.6 Quality issues

The quality of the raw material used in the processing industry determines to a large extent the quality of the finished product. Raw materials of poor quality cannot be expected to result in a final product of high quality even with the best processing methods. Therefore, gaining an understanding of the nature of the raw material and of its possible defects is an essential step in building quality into a product. Likewise thorough knowledge of the likely effects of defects, defective raw materials on both processing efficiency and quality of finished product is important. The bulb of garlic should have been harvested at proper maturity stage and tacked in windrows to cure. After about a week or when they have dried thoroughly, the bulbs are topped by cutting off leaves and roots with shears. Diseased and damaged bulbs are sorted out in the field. The bulbs of a variety should be thoroughly sorted and graded. The cloves of garlic variety should be sound and practically free from mould, disease, soil outer skins, stems, leaves and roots as per International Standard ISO-5560: 1997.

- *General*: Dehydrated garlic shall conform to the requirement of this International Standard and on rehydration shall regain characteristics similar to those of fresh garlic.
- *Colour*: The colour of dehydrated garlic shall be the characteristic of the cultivar used, i.e. between white and pale cream. The product shall be practically free from scorched, toasted and baked particles.
- *Odour*: Dehydrated garlic after rehydration by the method specified under the International Standard shall have a characteristic, pungent odour, free from foreign odour and off odour such as those coming from mouldy, rancid, fermented or burnt particles.
- *Flavour*: The flavour of the dehydrated garlic is assessed after rehydration in accordance with the method specified under the International Standard. It shall be the characteristic of parboiled garlic and free from foreign flavour and off flavour such as those coming from mouldy, rancid, fermented or burnt particles.
- *Freedom from insects, moulds, etc.*: Dehydrated garlic shall be free from live insects and practically free from moulds, dead insects, insect fragments and rodent contamination visible to the naked eye or with such magnification as may be necessary in any particular case. In case of dispute, the contamination of garlic in powder form shall be determined by using the method specified in ISO-1208.
- *Extraneous matter*: The total percentage of extraneous matter, i.e. vegetable matter originating exclusively from plants, such as particles from skins and roots shall not exceed 0.5% (m/m).

Table 16.5 Chemical requirements of dehydrated garlic

Characteristic	Requirement	Test method
Moisture content, % (m/m), max.	8	ISO 939
Total ash, % (m/m), on dry basis, max.	5.5	ISO 928
Acid-insoluble ash, % (m/m) on dry basis, max.	0.5	ISO 930
Volatile organic sulphur compounds content, % (m/m) on dry basis, min.	0.3	ISO 5567
Cold-water-soluble extract, % (m/m) on dry basis,		
min.,	70	ISO 941
max.	90	

Dehydrated garlic may be divided into the broad categories given below:

- *Dehydrated garlic slices*
  It is a product obtained by cutting garlic cloves into slices and removing broken pieces smaller than 4 mm by sieving.
- *Dehydrated garlic flakes or pieces*
  These are the products passing through a sieve of aperture size from 1.25 mm to 4 mm according to the case. The particles do not have any definite shape.
- *Dehydrated garlic grits*
  It is a product passing through a sieve of aperture size 250 μm to 1.25 mm.
- *Powdered garlic*
  It is a homogenous product 95% of which passes through a sieve of aperture size 250 μm.

Dehydrated garlic shall comply with the requirements for chemical and physical properties specified in Table 16.5 when tested by the specified method. M/s. Garlico Industries, Mandsaur, Madhya Pradesh, India has also given the specifications of garlic powder as required in the United States (Table 16.6).

Requirements for sampling are as follows:

- *Dehydrated garlic powder or grits*: Sampling of the product is done in accordance

Table 16.6 Specifications of garlic powder

Parameter	Standard
Description	Off-white/Yellow colour powder
Allicin yield	Not less than 12,500 ppm
Alliin	Not less than 28,000 ppm
Gamma Gluamylcysteins	Not less than 6,000 ppm
Total Thiosulphinates	Not less than 13,000 ppm
Total Sulphur	Not less than 6,000 ppm
Moisture	6% maximum
Granulation	+35 Mesh-max. 1%
	+45 Mesh-max. 1%
	+80 Mesh-max. 15%
Total Plate Count	100,000 Cfu/g maximum
Mould Content	1000 Cfu/g maximum
E.Coli	None Detected
Salmonella	None Detected

with ISO 948 using a conical sample or other suitable implement to remove aseptically or representative sample.

- *Dehydrated garlic slices, flakes or pieces*: Certain problems arise as a result of the friability of the product and the danger of settling within the container. It may, therefore, be necessary to take the entire contents of a single container because, during transport, the garlic may settle with the larger pieces towards the top and smaller pieces towards the bottom.
- *Test methods*: The samples of dehydrated garlic shall be tested for conformity with the requirement of this International Standard by following the methods of physical, organoleptic and chemical analysis specified above and in Table 16.5.

As far as packing and marking are concerned, dehydrated garlic shall be placed in clean, sound and dry containers made of a material which does not affect the product but which protects it from light and from ingress of moisture. The packaging shall also comply with any national legislation relating to environmental protection. The following particulars shall be marked directly on each package or shall be marked on a label attached to the package:

- name of the product, botanical name and trade names, if any;
- name and address of the producer or packer or trademark, if any;
- code or batch number;
- net mass;
- producing country;
- any other information requested by the purchaser, such as year of production and date of packing, if known;
- reference to this International Standard; and
- whether the product contains additives, and if so, which ones, in the case of countries where they are permitted.

Methods of rehydration and sensory evaluation of dehydrated garlic are:

- *Garlic slices*: Vessel, of about 500 ml capacity made of a material which will not impart a foreign taste or affect the colour of the preparation, dish made of porcelain or white earthenware and stainless steel spoon are the apparatus used in rehydration. Natural, potable water as neutral as possible is used. Sample of 10 g ± 0.1 g is weighed and transferred to the vessel containing 500 ml of cold water. It is then boiled at 99ºC, keeping the vessel covered for 10 minutes ±1 min. Volume is made up to 500 ml with cold water and then poured into the dish. Immediately then sensory evaluation of appearance of the cooking water (colour and clarity), colour of the preparation, odour, tenderness and flavour is carried out.
- *Garlic powder, grits, flakes or pieces*: Vessel of about 1000 ml capacity made of a material which will not impart a foreign taste or affect the colour of the preparation, dish made of porcelain or white earthenware, and stainless steel spoon are the apparatus used in rehydration. Flour made from durum wheat from the most recent harvest and known to be of good quality is used along with natural, potable water as neutral as possible are used as reagents. 1000 ml of cold water is transferred to the vessel and 30 g of the flour is added while stirring continuously. The mixture is then heated and stirred continuously until it reaches boiling point and then simmered for 2 minutes. Weighing is done to the nearest 0.001 g, 0.4 g of the garlic then placed in the dish. 250 ml of the medium prepared is added and allowed to stand for 5 minutes. Stirring is done from time to time. Sensory evaluation is then done for odour and flavour.

Table 16.7 Microbiological characteristics of dehydrated garlic

Characteristic	Recommended specification M	M	Test method
Microorganisms at 30ºC, per gram, max.	10^5	10^6	ISO 4833
Presumptive *Escherichia coli*, per gram, max.	10	10^2	ISO 7251
Yeasts and moulds at 25ºC, per gram, max.	10^3	10^4	ISO 7954
Clostridium perfringens, per gram, max.	10	10^2	ISO 7937
Staphylococcus aureus, in 1 g	Absent		ISO 6888
Salmonella, in 25 g	Absent		ISO 6579

Tests conducted in laboratories representing the producers and the users of this product have shown that the microbiological characteristics as given in Table 16.7 can be considered as acceptable. These are for information only.

Packages of dehydrated garlic should be stored in covered premises, well protected from the sun, rain and excessive heat. The storeroom should be dry, free from unpleasant odours and protected against the entry of insects and other vermin. While transporting, the containers should be clearly marked with warning against careless handling which might lead to perforation of the containers. They should be dry and cool and stored well away from ships' boilers and bilges.

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17

Ginger

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17.1 Introduction

The spice ginger is obtained from the underground stems or rhizomes of *Zingiber officinale* (Rosc.), a herbaceous tropical perennial belonging to the family Zingiberaceae. In cultivation, it is usually grown as an annual. The whole plant is refreshingly aromatic, but it is the underground rhizome, raw or processed, that is valued as spice. Its medical value is increasingly being recognized. Ginger originated in South-East Asia, probably in India (Burkill, 1966; Purseglove *et al*., 1981). The name itself supports this view. The Sanskrit name 'Singabera' gave rise to Greek 'Zingiberi' and later the generic name Zingiber.

Ginger (*Zingiber officinale* Rosc.) is a monocotyledon belonging to the family Zingiberaceae and to the order Zingiberales. In the Zingiberaceae, it belongs to the subfamily Zingiberoideae, which are aromatic with unbranched aerial stems, distichous leaves, open sheaths and hypogeal germination, mainly confined to the old world tropics with the centre of distribution in Indo-Malaysia (Purseglove *et al*., 1981). Among them, ginger is a slender perennial herb, 30–100 cm tall with palmately branched rhizome-bearing leafy shoots. The leafy shoot is the pseudostem formed by leaf sheath and bears 8–12 distichous leaves. The inflorescence is a spike which generally springs directly from the rhizome.

The subfamily Zingiberoideae is also noted for two important spice crops, turmeric (*Curcuma longa* L.) and cardamom (*Elettaria cardamomum* Maton). It also includes a number of subsidiary spice plants belonging to the genera Aframomum, Amomum, Kaempferia, Languos (Alpinia) and Phaeomena (Nicolaia). The genus Zingiber Boehm has about 80–90 species of perennial rhizomatous herbs distributed throughout South-East Asia and extending to Queensland and Japan (Purseglove *et al*., 1981).

17.2 Chemical structure

The ginger rhizome contains steam volatile oil, fixed fatty oil, pungent compounds, resins, proteins, cellulase, pentosans, starch and mineral elements. The composition of

these components varies with type of cultivar, region, agroclimatic conditions, maturity and nature of rhizome, i.e. fresh or processed (Purseglove *et al*., 1981). The dry ginger on average contains moisture (10.85%), volatile oil (1.8%), oleoresin (acetone extract) (6.5%), water extract (19.6%), cold alcohol extract (6.0%), starch (53%), crude fibre (7.17%), crude protein (12.4%), total ash (6.64%), water soluble ash (5.48%) and acid insoluble ash (0.14%) (Peter and Kandiannan, 1999).

The characteristic organoleptic properties of ginger are due to steam volatile oil and non-volatile solvent extractable pungent components. The pleasant aroma of ginger is caused by more than 70 constituents present in steam volatile oil. Among them the sesquiterpene hydrocarbon (-)-α-zingiberene predominates and accounts for 20–30% of the oil obtained from dry ginger (Purseglove *et al*., 1981). The warm pungent taste is caused by a number of components predominated by gingerols followed by shogaols and zingerone (Kulka, 1967). The aroma and flavour of fresh ginger will be different from dry ginger as some of the volatile oils will be lost by evaporation during drying (Purseglove *et al*., 1981).

17.3 Production

Ginger is cultivated in several parts of the world, the most important producing regions being India, China, Nigeria, Sierra Leone, Indonesia, Bangladesh, Australia, Fiji, Jamaica and Nepal. Among them India and China are the dominant suppliers to the world market (Table 17.1).

In terms of quality, Jamaican and Indian ginger are considered superior followed by West African. Jamaican ginger possesses delicate aroma and flavour and is sometimes considered as first grade. Indian ginger, entering the world market as 'Cochin' and 'Calicut' ginger, has a lemon-like byenote for which some have a preference over Jamaican ginger. Chinese ginger is low in pungency and mainly exported as preserves in sugar syrup or as sugar candy. Nigerian and Sierra Leone dried ginger possess somewhat camphoraceous and coarser odour and is rich in aroma and pungency factors. There is demand for them for oil distillation and oleoresin extraction.

Primary products of ginger rhizomes for flavouring purposes are fresh ginger, preserved ginger in syrup or brine and the dried ginger. Secondary products are ginger powder, oils and oleoresins from dry ginger.

Table 17.1 Area and production of ginger in the important ginger producing countries (1990, 1995, 1999)

Country	1990		1995		1999	
	Area (ha)	Production (tonnes)	Area (ha)	Production (tonnes)	Area (ha)	Production (tonnes)
India	54,000	154,000	90,100	170,800	70,000	235,000
China	5,333	54,284	12,502	130,698	13,450	157,018
Nigeria	84,000	42,000	140,000	79,000	145,000	80,000
Bangladesh	6,967	42,830	6,900	39,000	7,700	39,000
Jamaica	274	865	161	452	180	620
Nepal	1,250	3,500	1,000	3,000	1,200	3,200
Indonesia	9,612	79,891	10,000	82,631	9,900	80,351

Source: FAO Statistical Database lllp;//www-fao.org

17.3.1 Fresh ginger

Fresh ginger is outstanding for flavouring as it contains the full note of the spice compared to other products from it. Fresh rhizomes with low fibre content but rich in aroma, pungency, fat and protein are preferred for green ginger purposes. The crop for this purpose can be harvested from 180 to 195 days after planting. Further maturity causes a progressive increase in crude fibre and decrease in protein and fat content.

17.3.2 Preserved ginger

Immature green ginger is preserved in brine or sugar syrup. Crystallized ginger is also made from the ginger in sugar syrup by further processing. Crystallized ginger is the peeled ginger impregnated with sugar syrup, dried and coated with crystalline sugar. Succulent ginger rhizomes with very little fibre and less pungency are preferred for preserved ginger. The raw material has to be harvested within 195 days of planting. The processing technology of preserved ginger varies with country. (A basic idea will be obtained from Chinese technology.)

17.3.3 Dry ginger

Dry ginger obtained by drying of fresh ginger comes in the spice trade for the preparation of ground ginger and extraction of oleoresin and oil. It is available in a number of physical forms. It can be peeled (scraped or uncoated) or non-scraped (coated or non-peeled) and sometimes partially peeled or rough scraped. In the scraped grade, the cork skin has been removed clearly without damaging the underlying tissue. Grades designated as 'bleached' or 'limed' are also available. They are prepared from clean peeled or partially peeled whole rhizomes by treating with lime or sulphurous acid to achieve white colour. Physical grades like black ginger, splits and slices are also available.

Dried ginger is prepared from mature rhizomes which have developed full aroma, flavour and pungency, and harvesting is usually carried out at between eight to nine months after planting. For dry ginger making, cultivars with medium-sized rhizomes with high curing percentage are preferred. The processing of dry ginger involves the following steps:

1. Removal of roots and thorough washing of rhizomes.
2. Preparation of rhizome for drying, which involves either peeling, splitting or slicing. When whole-coated rhizomes are to be dried, preparation is by immersing in boiling water for about 10 minutes. Black ginger is prepared like this.
3. Sun drying: during drying, rhizomes lose moisture, about 60–70% of their weight, and achieves a final moisture of 7–12%.

Jamaican ginger is clean peeled using a special knife and, after thorough washing, sun dried. Indian ginger is rough scraped, non-bleached or bleached (limed). In this, the skin is partially scraped off with a sharpened piece of bamboo. Steel knives are not used as they stain the produce. Mechanization is possible in dry ginger processing, in grading, peeling and drying. But mechanical grading and peeling produce an inferior quality produce. Most of the producing countries resort to traditional methods which employ manual labour mainly.

The appearance, the content of volatile oil and fibre, the pungency level and a subjective assessment of aroma and flavour are important in the quality evaluation of

dried ginger. Cleanly peeled dried ginger in the whole form possessing the best appearance generally find a place in the grocery trade. Lower grades of clean peeled, coated whole, split and sliced types are used for blending in the preparation of powdered mixed spices. All types may be used for oil distillation and oleoresin extraction, but the coated types are the most extensively used for these purposes.

17.3.4 Ginger powder

Ginger powder is made by pulverizing dry ginger to a mesh size of 50 to 60. Ginger is ground to release the flavour, the finer the powder, the more readily available the flavour and readily dispensable in the matrix. Some flavour may be lost by heat development during grinding. This can be minimized by adopting cryomilling and freeze grinding.

17.3.5 Ginger oil

Ginger oil is produced commercially by steam distillation of freshly ground dry ginger. The yield of oil varies from 1.5 to 3.0% with an average of 2.0%. The oil obtained is a green or yellow mobile liquid which becomes viscous on ageing (Purseglove *et al.*, 1981). The most suitable material for oil distillation is coated African ginger, followed by Nigerian splits and Cochin ginger. Ginger oil can also be recovered by steam distilling fresh ginger peelings and the yield is 1.5 to 2.8%.

17.3.6 Ginger oleoresin

Ginger oleoresin is obtained by extraction of powdered dry ginger with suitable organic solvents like alcohol, acetone and ethylene dichloride, etc. Concentration of solvent extract under vacuum and complete removal of traces of solvent yields 'oleoresin of ginger'. The yield, flavour and pungency of extracted oleoresin vary with cultivars, maturity of rhizome, choice of solvent and the method of extraction employed. Generally a yield of 3.9–9.3% with an average of 6.5% on dry weight of ginger is obtained. Commercial ginger oleoresin usually has a volatile oil content of 25–30% and a replacement strength of 1 kg oleoresin for 28 kg good quality ground spice. They are offered to the consumer in liquid form or dispensed on sugar or salt.

17.4 Main uses in food processing

The refreshing pleasant aroma, biting taste and carminative property of ginger make it an indispensable ingredient of food processing throughout the world. Fresh ginger, ginger powder from dry ginger, oleoresin and oil are all used for this purpose. Fresh ginger is unique for its flowery flavour and spicy taste. Hygienic oleoresin and oil in convenient consumer friendly packing and dispenser system find a place in the culinary art of developed countries and upper society strata of developing countries.

Ginger preserve and candy are also in great demand for use in confectionery. Chocolate manufacturers utilize the preserve for enrobing. It is also used in jams and marmalades. The syrup in which ginger is preserved is valued for pickle and sauce making. It is also used in the production of ginger bread (Pruthi, 1993).

In western countries ginger is used widely for culinary purposes in gingerbread, biscuits, cakes, puddings, soups and pickles. It is also used in the production of alcoholic

beverages like ginger beer, ginger ale, and ginger wine. Earlier it was much favoured for spicing wines and possets (Purseglove *et al*., 1981). In the East, fresh ginger chopped into small bits and in the ground form are very much used in vegetarian and non-vegetarian food preparations. It is also used in pickling, soft drink making, confectionery and curry powder preparations. The unique speciality of Chinese cookery owes very much to the use of fresh ginger as ground paste. In India, in meat and fish dishes it is indispensable to make it palatable and digestible. Buttermilk containing crushed fresh ginger, green chillies, salt and curry leaf is a delicious drink and appetizer of South India. 'Puliyingi' a curry prepared from finely chopped fresh ginger and ripe tamarind fruit extract as main ingredients is unique in taste and is indispensable in social and festival feasts of the Malabar coast. Certain Indian recipes for ginger wine, fish, meat and tomato curry preparations are given below:

Ginger wine
Ingredients

Fresh ginger cut into pieces	1 kg
Yeast	small pinch
Sugar	1 kg
Water	1.5 litre

Method

1. Cook the ginger pieces in a pressure cooker for 10 min.
2. When cold, keep for fermentation along with $\frac{3}{4}$ kg sugar and yeast for 21 days.
3. Every other day the contents are turned.
4. On completion of fermentation, wine is squeezed out from the fermented ginger.
5. To improve the appearance, the remaining $\frac{1}{4}$ kg sugar is burned to brown colour and mixed with the wine.

Consuming one teaspoon of ginger wine daily is good for digestion and health.

Spicy Lamb Fry Masala
Ingredients

Lamb	750 g
Onions	2 medium size
Ginger	20 g
Garlic	4 cloves
Green chillies	1 teaspoon
Garam masala powder	1 teaspoon
Curry leaves	10 g
Coriander powder	1 tablespoon
Red chilli powder	4 teaspoon
Turmeric powder	½ teaspoon
Capsicum	¼ teaspoon
Fresh tomatoes	2
Ground black pepper	2 teaspoons
Coriander leaves	to garnish
Lemon juice	to taste
Salt	to taste

Oil	20 g
Fresh lemon	1

Method

1. Cut the meat into half-inch cubes and wash them.
2. Cook meat with salt along with sliced onions, ginger, garlic, red chilli powder, turmeric powder, garam masala powder and coriander powder on a slow fire until meat is tender and all water has evaporated.
3. Slice some onions and sauté them in a little oil.
4. Add cooked meat and sauté it until well fried.
5. Add sliced tomatoes, capsicum, green chillies and fry them.
6. Add ground black pepper, chopped coriander leaves and lemon juice.
7. Serve with a garnish of onion rings, curry leaves and sliced fresh lemon.

Garcinia fish curry
Ingredients

Fish	½ kg
Chilli powder	4 tablespoons
Turmeric powder	1 teaspoon
Garlic flakes	10
Ginger julienne	1 inch piece
Garcinia	4 pods
Coconut oil	2 tablespoons
Mustard	1 tablespoon
Fenugreek	4 seeds
Curry leaves	1 spring
Salt	to taste
Water	2 glasses

Method

1. Cut the fish into dices and wash under running water.
2. Heat up an earthenware pot, pour the coconut oil, crackle mustard, fenugreek.
3. Sauté garlic, ginger and curry leaves and add chilli powder and turmeric powder.
4. Stir till it gets cooked and add water to it.
5. Add cleaned garcinia pods and the diced fish into it.
6. Cover the pot and boil it until fish gets cooked.
7. Check for the seasoning and finish it off with a dash of coconut oil.

Tomato curry
Ingredients

Onions	2 medium
Tomatoes	4 medium
Cumin powder	1 teaspoon
Ginger	10 g
Coriander powder	1 teaspoon
Turmeric powder	1 teaspoon
Dry red chillies	4

Mustard	1 teaspoon
Oil	2 tablespoons
Cashew nut	10 g
Chilli powder	1 tablespoon
Yoghurt	2 tablespoons

Method

1. Fry sliced onions until brown.
2. Grind coriander powder, chilli powder and turmeric powder with sliced ginger into a smooth paste along with yoghurt.
3. Add ground condiments to browned onions.
4. Cut tomatoes into quarters and add to brown mixture.
5. Fry for 2 minutes.
6. Add 2 cups of water and boil for 5 minutes.
7. Add salt.
8. Give a tempering of mustard, red chillies and cashew nuts.

17.5 Functional properties

The nutritive value of ginger is given in Table 17.2.

Ginger is much used in traditional Indian (Ayurveda) and Chinese medicine (Sivarajan and Balachandran, 1994). Recent research has supported its functional value in the following areas:

- Ginger has excellent antioxidant properties. Antioxidants are increasingly linked to the prevention of certain cancers (Kikuzaki *et al*., 1994) and coronary heart disease, as well as their more established role in preserving lipid-based foods. Studies include the role of components such as gingerol in inhibiting linoleic acid autoxidation (Kikuzaki and Nakatani, 1993), extending the shelf-life of meat (Ziauddin *et al*., 1995), dehydrated pork (Fuijo *et al*., 1969) and fermented meat sausage (Al-Jalay *et al*., 1987).

Table 17.2 Nutritional composition of dry ginger (per 100 g)

Composition	Quantity
Water (g)	7.0
Food energy (k cal)	380
Protein (g)	8.5
Fat (g)	6.4
Carbohydrates (g)	72.4
Ash (g)	5.7
Calcium (g)	0.1
Phosphorus (mg)	150
Sodium (mg)	30
Potassium (mg)	1400
Iron (mg)	11.3
Thiamine (mg)	0.05
Riboflavin (mg)	0.13
Niacin (mg)	1.90
Vitamin activity (RE)	1.5

- There are a number of studies of the antimicrobial activity of gingerols, for example in relation to *Bacillus subtillis* and *E. coli* (Yamada *et al*., 1992) and Mycobacterium (Galal, 1996; Hiserodt *et al*., 1998)
- Ginger has a known influence on the eicosanoid cascade which influences such functions as wound healing, inflammation and platelet aggregation, and is involved in conditions such as arteriosclerosis (Srivasta, 1986; Sankawa, 1987; Kiuchi *et al*., 1992; Kawakishi *et al.*, 1994).
- Ginger has beneficial effects on the digestive system, enhancing gastrointestinal motility, and is used traditionally for the treatment of stomach ache, vomiting and indigestion (Yamahara *et al*., 1990). It has also been investigated for its gastroprotectant and anti-ulcer activity (Yamahara *et al*., 1988; Yamahara *et al*., 1992; Yoshikawa *et al*., 1994).
- A recent study has investigated antitumour properties in gingerol, notably in inhibiting skin cancer (Park *et al*., 1998).
- Ginger checks cholesterol biosynthesis and thereby inhibits hypercholesterolema (Tanabe *et al*., 1993). Its role in Chinese herbal medicine in controlling obesity has also been investigated (Wijaya and Wu, 1995).

The various functional properties of ginger are discussed in detail in Kikukazi (2000).

17.6 Quality specifications

India and China are the world's largest producers and exporters of ginger. Other important producers are Jamaica, Nigeria, Sierra Leone, Thailand and Australia. USA, United Kingdom, Germany, Japan, Saudi Arabia, Singapore, Hong Kong and Canada are the major importers of ginger. The importing countries give top priority to the health of their citizens and it is important that the ginger imported conforms to the quality standards prescribed by the particular country. Exporting countries also fix standards to supply required quality products to the consumers.

17.6.1 Indian standards

In India, the world leader in ginger export, the Bureau of Indian Standards (BIS) has AGMARK grading system for dry ginger and ginger powder. It categorizes Calicut ginger and Cochin ginger to different grades as given in Table 17.3 based on the size of rhizome, extraneous matter, lime content as calcium oxide and very light pieces present. Among them only garbled non-bleached 'Cochin' and Calicut meet the United Kingdom Standards.

17.6.2 United States standards

The United States Government Standard defines ginger as the washed and dried or decorticated and dried rhizome of *Zingiber officinale* Rosc. The standards stipulated for ginger are given in Table 17.4.

The ginger imported to the United States should also conform to the cleanliness specifications stipulated by the American Spice Trade Association (ASTA) (Table 17.5) and also the regulations enforced by the Food and Drug Administration (FDA). The FDA has fixed defect action levels for whole ginger as shown in Table 17.6.

Table 17.3 Grades of whole dry ginger with specifications as per the ISI specification No. IS:1908-1961

Grade	Special characteristics	Size of rhizome	Extraneous matter in percentage (max.)	Light pieces by count in percentage (max.)	Lime as CaO by weight in percentage (max.)
1. NGK/NGC Garbled, non-bleached Calicut/Cochin	Pieces irregular in shape and size. Pale brown, fibrous with peel not entirely removed. Light pieces removed by garbling	Not less than 20 mm in length	2	Not allowed	Nil
2. BGK/BGC Garbled bleached Calicut/Cochin	Pieces irregular in shape and size. Pale brown, fibrous with peel not entirely removed. Lime bleached. Light pieces removed by garbling	Not less than 20 mm in length	2	Not allowed	2.5
3. NUGK/K Ungarbled non-bleached Calicut/Cochin	Pieces irregular in shape and size. Pale brown, fibrous with peel not entirely removed.	Not less than 20 mm in length			
a) Special			3	5	
b) Good			4	10	
c) Non-specified			Not specified		
4. BUGK/C Ungarbled Bleached Calicut/Cochin	Pieces irregular in shape and size. Pale brown, fibrous with peel not entirely removed. Lime bleached.	Not less than 20 mm in length			
a) Special			3	5	4
b) Good			4	10	6
c) Non-specified			Not specified		

Table 17.4 US government specifications for dry ginger and powder

Total ash per cent not >	7.0
Acid insoluble ash per cent >	1.0
Crude fibre per cent not >	8.0
Volatile oil expressed as ml per 100 g not <	1.5
Moisture per cent not >	12.0
Starch per cent not <	42.0
Sieve test (for powdered ginger only)	
US standard sieve size	110.30
Percentage required to pass through not <	95.0

From US Federal Specifications: Spices ground and whole and spice blends. No.EE-S-531 H, June 5, 1975 (Purseglove *et al.*, 1981).

Table 17.5 ASTA cleanliness specifications

Factors specified (not >)	Ginger
Mammalian excreta, mg per 1b	3
Other excreta, mg per 1b	3.0
Extraneous matter, per cent by weight	1.00
Whole dead insects, per 1b by count	4
Insect defiled/infested, per cent by weight	SF (3)
Mouldy ginger, per cent by weight	SF (3)

Source: Sivadasan (1998).

Table 17.6 Defect action levels fixed by FDA

Defect	Action level
1) Insect and mould infestation (MPM-V 32)	Average of 3% or more of pieces by weight are insect infested and/or mouldy
2) Mammalian excreta (MPM-V 32)	Average of 3 mg or more of mammalian excreta per pound

Source: Sivadasan (1998).

Table 17.7 Tolerance limits for certain pesticides and aflatoxin

Pesticides	Tolerance limit
Aldrin	0.05 ppm
Dieldrin	0.05 ppm
BHC	0.05 ppm
Chlordane	0.1 ppm
Heptachlor	0.1 ppm
Malathion	0.1 ppm
Parathion	0.3 ppm
Carbonde	0.3 ppm
DDT, Endrin	Not permitted
Aflatoxin B1	2 ppb (max.)
B1+B2+G1+G2	4 ppb (max.)

Source: Spices Board (1995).

Table 17.8 Cleanliness and commercial specifications for whole dry ginger imported to some European countries

Sl. No.	Factors	Germany	The Netherlands	UK	ESA
1	Extraneous matter (% wt)	–	–	1.0	1.0
2	Moisture (% wt)	12.5	10.0	12.0	12.0
3	Total ash (% wt)	7.0	8.0	6.0	8.0
4	Acid insoluble ash (% wt)	1.0	3.0	1.0	2.0
5	Volatile oil (% wt) (min.)	2.0	1.5	1.5	–

Source: Kalyanaraman (1998).

Besides the above the FDA has also specified tolerance limits for pesticide and aflatoxin as shown in Table 17.7.

17.6.3 European Standards

Importers in Germany, The Netherlands, United Kingdom and the ESA have laid down specifications for whole dry ginger and powder regarding commercial, cleanliness and health requirements (Table 17.8).

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18

Kokam and cambodge

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18.1 Introduction

Kokam (*Garcinia indica* Choisy) is a slender evergreen small tree with drooping branches which attain a pyramidal shape on maturity. It is a dioecious tree growing up to 18 m in height. The fruit is spherical, as large as a small orange, purple throughout, not grooved, having 5–8 seeds compressed in an acid pulp. It is a crop of oriental origin preferring warm and moderately humid tropical climate with a total rainfall range of 2500–5000 mm. It grows under a mean annual temperature of 20–30ºC, 60–80% humidity and up to an altitude of 800 m from mean sea level. Kokam plants originate and grow wild in the tropical forests of Western Ghats of India. It prefers partial shade, and is more associated with fire protected secondary forests.[1] Extreme acidity is harmful to the crop. The tree grows extensively in the Konkan region of Maharashtra, Goa, coastal areas of Karnataka and Kerala, evergreen forests of Assam, Khasi, Jantia hills, West Bengal and Gujarat.[2] It is a popular tree spice having tremendous potential and in South Indian curries, it is used instead of tamarind, and also has many medicinal properties. The juice of the fruit is used as a mordant and the expressed oil of the seed is the kokam oil of the natives, extensively used to adulterate ghee.[3] The seeds of the fruit yield valuable edible fat known in commerce as kokam butter.

Cambodge (*Garcinia cambogia* Desr.) is a tropical fruit commonly known as Malabar tamarind and belongs to the family Clusiaceae[4] earlier known as Guttiferae.[5] It is a medium-sized evergreen dioecious tree with rounded crown and horizontal or drooping branches generally attaining a height of 18 m. The fruit is a berry having the size of a small apple, yellow or red, 6–8 grooves forming blunt lobes with tough rind, 6–8 seeds and succulent aril.[6] The fruits may vary in size weighing 50–180 g. It is a native of Western Ghats of Kerala (India) and Malaysia. It grows in the evergreen forests of the Western Ghats in South India and its habitat extends from Konkan southward to Travancore and into the Shola forest of Nilgiris where it can reach an altitude of up to 2000 m above mean sea level.[4] In Kerala, it is very popular in the Central Travancore areas and Kerala seems to be one of the centres of origin of cambodges where maximum diversity is seen.[7] It is fairly common and abundant in the forests of western Sri Lanka

from sea level to 600 m and in Malaysia.[8] It is widely distributed in the evergreen forests of Western Ghats from South Kanara and Mysore to South Kerala up to the low lying reclaimed lands bordering the backwaters.[9] The plant flowers in the hot season and the fruits ripen in the rains. Cambodge fruit has excellent therapeutic value and the dried rind is a popular fruit spice used in cookery as an important ingredient in many dishes for flavouring curries in place of tamarind or lime.

18.2 Chemical structure

Kokam contains about 10% malic acid and a little tartaric and citric acid.[10] Composition of fresh kokam rind is as follows (as reported by Sampathu and Krishnamurthy[11]):

- moisture (%) 80
- protein (%) (N × 6.25) 1.92
- crude fibre (%) 14.28
- total ash (%) 2.57
- tannins (%) 2.85
- pectin (%) 5.71
- starch (%) 1.00
- crude fat (%) 10.00
- pigment (%) 2.00
- ascorbic acid (%) 0.64
  (hexane extract)
- acid (as hydroxy citric acid) 22.80
- pigment (%) 2.4
- ascorbic acid (%) 0.06
- carbohydrates by difference (%) 35
  (Values are expressed on moisture-free basis.)

Cambodge rind is rich in non-volatile acids.[12] The fruit rind which is of commercial value contains 30% acid (citric acid) on the dry basis and it is essentially (-)-hydroxycitric acid.[13] The dried rind also contains 10.6% tartaric acid, 15% reducing sugars and 1.52% phosphoric acid.[14] Of the total acids present in the rind, nearly 90% is non-volatile. Sherly[15] reported that the rind of *G. cambogia* had an average of 6.68% acidity, 7.2 mg/100 g ascorbic acid, 8° brix T.S.S and 1.04% reducing sugar. Mucilage around the seed contains 2.64% reducing sugar and 3.3% acidity and on average, a loss of 75% weight was recorded on drying.

The rind of garcinia fruits such as kokam and cambodge are the richest sources of (-)-hydroxycitric acid (HCA), which has an excellent therapeutic value against obesity. Earlier the acid present in the rind was misidentified as citric acid. Later Lewis and Neelakantan[16] isolated the acid and identified it as hydroxycitric acid, which is present in the isomeric form. (-)-Hydroxycitric acid is valued for its taste characteristics and health benefits. The isolated HCA is unstable leading to formation of (-)hydroxycitric acid lactone (HCAL) and organic acids in the garcinia fruits and garcinia products (extracts and salt derivatives) co-occur. The structures of HCA and HCAL are shown in Fig. 18.1. The sour taste components are due to HCA[13,16,17] present in the range of 10–30% in the rinds. HCA and HCAL co-occur in fruits and extracts and HCA is rapidly converted into lactone during the concentration process.[17] Varying amounts of citric acid (1–3%) are present in the fruit and in the products. The total acids expressed as HCA in the fruits

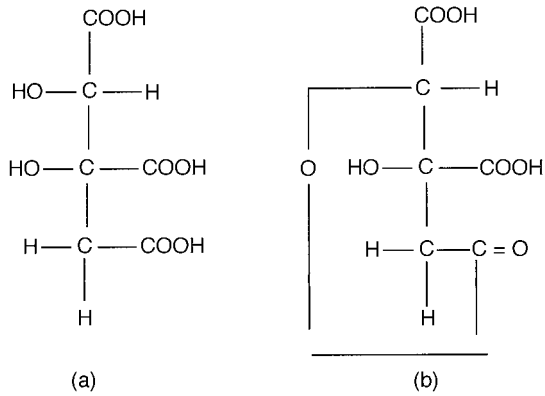

Fig 18.1 Structure of (a) (-)-hydroxycitric acid (HCA) and (b) (-)hydroxycitric acid lactone (HCAL)[18]

ranged from 19 to 26% and HCAL content ranged from 9 to 12%. HCAL can be converted to HCA by the addition of NaOH and heating.[18]

Kokam butter is rich in combined stearic and oleic acids. It contains about 75% of mono-oleodisaturated glycerides and possesses a fairly low melting point and considerable brittleness. The chemical characteristics of the fat are:[19,20]

- melting point 39–43ºC
- sap value 189
- iodine value 34.7–36.7
- unsap matter (%) 1.4
- free fatty acids as (%) as oleic 7.2

The component fatty acids percent by weight are:

- myristic 0 to 1.2
- palmitic 2.5 to 5.3
- oleic 39.4 to 41.5
- linoleic 1.7

The seed cake after the extraction of oil contained crude protein 16.6%, crude fibre 4.4%, ether extract 1.6%, nitrogen-free extract 70.0% and ash 7.4%.

The seeds of cambodge yield 31% of edible fat, resembling kokam butter, and are rich in oleic and stearic acid. The fat has a granular structure and the following properties:[21]

- melting point 29.5ºC
- acid value 5.0
- sap value 203.5
- acet value nil
- iodine value 52.5
- R.M. value 0.2
- unsap matter (%) 1.0
- titre 51.2º

18.3 Production

India is the major producer of kokam and cambodge. The important producing areas for kokam in India are Western Ghats, Coorg, Wynad and Ratnagiri.[21] It is estimated that in the Konkan region alone about 4000 tonnes are produced.[11] Western Ghats region contains about 15 lakh trees and the estimated yield is 10,000 bags each with 100 *seers* of seeds.[19] Kokam is exported mainly in the forms of fruit, oil (kokam butter) and syrup. Indian kokam is popular in several countries like UK, Canada, Australia, Hong Kong and the Middle East. Zanzibar is the main importer of kokam from India. It is also reported that Italy and some other foreign countries are importing kokam fat from India for use in confectionery preparations.[11] In the case of cambodge, sizeable quantities are exported from parts of South India (particularly Alleppy in Kerala State) to meet the demands of Bombay (presently known as Mumbai) and Gujarat markets; it offers bright prospects for expansion of the market in North India.[6]

18.3.1 Kokam

The kokam fruit has an agreeable flavour and sweetish acid taste. The normal shelf-life of the fresh fruit is about five days. Hence sun drying is practised for preservation. For sun drying the fresh fruits are cut into halves and the fleshy portion containing the seed is removed. The rind, which constitutes 50–55% of the whole fruit, is repeatedly soaked in the juice of the pulp during sun drying. About 6–8 days are required for complete drying. The product so dried constitutes the unsalted kokam of commerce. A salted variety wherein common salt is used during soaking and drying of the rind is also marketed.[11] Lonaval kokam, Pakali kokam, Khanee kokam and Khoba kokam are a few of the trade varieties. The seed contains about 32–35% fat and is extracted by one of several methods – boiling, cold extraction/churning of the powdered seeds by water or simple extraction:[8]

- *Boiling process*: The seed is cracked and the shell removed. The white kernel is then pounded in a large specially-made stone mortar and pestle. The pulp is put into an earthen or iron pan with some water and boiled. After some time it is poured into another vessel and allowed to cool. The oil which rises to the surface on cooling becomes gradually solid, and is strongly moulded by hand into egg-shaped balls or concavo-convex cakes.
- *Cold extraction/churning process*: The kernel is pounded as above and the pulp with some water is kept in a large vessel and allowed to settle for the night. During the night the oil rises to the surface and forms a white layer, which is removed in the morning. The mixture is then churned, and the oil which, like butter, rises to the surface in a solid form, is removed by hand. This process gives the best product and is most favourably performed in the cold season.
- *Simple extraction*: In this process, the kernels are pressed in an ordinary oil mill, like other oil seeds, and the oil is extracted.

Extraction is mostly on a cottage industry basis by crushing the kernels, boiling the pulp in water and skimming off the fat from the top; or by churning the crushed pulp with water.[21] Nowadays it is obtained by solvent extraction also. After extraction the crude kokam butter is sold as egg-shaped lumps, having a characteristic yellowish colour and greasy in nature. It also has a faint but not disagreeable odour. Refined and deodorized fat is white in colour and compares favourably with high-class hydrogenated fat. It is readily soluble in ether and slightly in rectified spirits, more in hot than in cold.[22]

18.3.2 Cambodge

Harvesting of cambodge coincides with the monsoon in South India. The fruits are harvested at ripening stage for getting good quality rind. Ripening takes five months from flowering. On abscission, the fruits are collected, then seeds and rinds are separated. A good percentage of fruits are wasted due to lack of proper processing and preservation technologies in the humid areas.[23]

The rind is detached from the kernel of under-ripe fruits, cut into half or sectioned into thicknesses varying inversely with the humidity of the weather. These are then spread in thin layers and dried in the sun for three to seven days to a moisture level of 15 to 20% and smoked.[24] Rinds are dried until they attain a coal black colour and characteristic acid taste. In Kerala mainly three types of drying procedures are practised.[25] They are sun drying, smoke drying and alternately under sun and smoke:

- *Sun drying*: In this method under-ripe fruits are harvested and the rind is detached. After removing the succulent aril and seeds, the fruit is cut into two equal halves. The rind is spread on a specially prepared floor or mat. If there is sufficient sunlight it takes six to seven days for complete removal of moisture and the rind attains a coal black colour. In some places the rind is hanged in the midrib of coconut leaves, the ends of which are tied to poles or trees. As the rind hangs on the midrib all parts get uniform heat. Cambodge dried by this method is considered to be the best by the locals. This method is followed in Thodupuzha and Vazhakulam areas of Kerala.
- *Smoke drying*: Since the harvest coincides with the monsoon, enough sunlight is not available for drying. In these conditions, after removal of seeds, the rinds are smoked on lofts above the fireplace. The rind gets dried by the heat and smoke from the hearth. It takes one week or more for complete drying. When large quantities are to be dried, lofts are prepared in such a way that heat is distributed uniformly on the platform. Coconut husk, shell and other wooden logs are used for burning. Along with this, fresh Eupatorium and Loranthus are used and by the slow burning of these, the rind is dried. This practice is followed in Parur, Kodungallur, Thiruvalla and Vazhakulam areas of Kerala.
- *Sun and smoke*: When there is no rain the rinds are dried under the sun and during the night smoke drying is practised. The dried rinds are preserved by rubbing with 50 ml of coconut oil and 150 g of common salt (sodium chloride) per kilogram of rind for storing for long periods. In some areas turmeric powder is also used.[25]

Commercially, cambodge concentrate is synthesized from the dried rind of cambodge largely capturing the flavour profile of the dried rind, which is used for preparing a variety of HCA products. The procedure is to extract the acid from the dry fruit rind by washing with water and to hydrolyse this extract by refluxing with alkali to convert any lactone present back into the acid. This is followed by precipitation with calcium chloride and drying. A properly prepared (-)HCA salt will be more stable and effective than the liquid form.[26]

18.4 Main uses in food processing

18.4.1 Kokam

The kokam rind is the richest source of natural red pigment anthocyanin, which has great market potential in developed countries.[2] Kokam rind contains two to three per cent anthocyanin pigments and is a promising source of natural colourant for acid foods.

Cyanidin-3-sambudioside and cyanidin-3-glucoside are the major pigments present in the ratio 4:1.[27] A new fat-soluble yellow pigment, namely garcinol, has been isolated from the fruit rind.[28]

Kokam fruit serves as a flavouring substitute and also used as acidulant in certain foods. It is a good source of acid and contains a substantial amount of malic acid (10%) and a little tartaric acid and citric acid.[21] The ripened rind and juice of kokam fruit are commonly used in cooking for preparing '*Soikadi*', a popular everyday food for each household in Konkan region. Kokam syrup has potential demand in the market. The dried and salted rind (amsol) is being used as a condiment in curries.[2] It is used as a garnish to give an acid flavour to curries and also for preparing attractive red pleasant flavoured cooling syrups for use during hot months.

The seed contains about 32 to 35% fat having food and non-food applications. Kokam butter is mainly used as an edible fat. It is also used as an adulterant of ghee. Kokam fat remains solidified at room temperature. It is edible, nutritive, demulcent, astringent and emollient.[10] It is also used as confectionery butter, and also for candle and soap manufacture. It can be used for the production of stearic acid from the fat with a yield of 45.7%. It can also be employed in the sizing of cotton yarn.[21] The cake left after the extraction of oil is used as manure. The barks of the trees are astringent and are kept and brought overseas to make vinegar.[8] The juice of the fruit is used by blacksmiths for melting iron and wood is well suited for paper making. Young leaf is acid and used in Amboyana in cooking fish.[29]

18.4.2 Cambodge

The dried rind is used as a condiment for flavouring curries in place of tamarind and lime. In Sri Lanka, the dried rind with salt is used for curing fish. The cured fish does not require prolonged washing prior to use.[24] The fruits are characterized by a sharp pleasant acidity. Though it is not eaten raw, it is included in curries as an appetizer in East India. The processed and dried pericarp is of great value for its delicate taste and flavour. The dried slices of this fruit, when used in place of tamarind in the preparation of fish and non-vegetarian curries is supposed to impart a special flavour and taste.[6] The dried rind with its rich acidity possesses marked antiseptic properties and it also counteracts the tang of salt.[12] It is also employed in veterinary medicine as a rinse for diseases of mouth in cattle. The dried rind is also used for polishing gold and silver. It is also a substitute for acetic and formic acids in the coagulation of rubber latex. The wood is used for posts and is suitable for matchboxes and splints. A translucent yellow resin obtained from the tree has purgative properties and is soluble in turpentine and makes a good varnish.[14,21,29] The yield of ordinary cambodge in colouring resin varies from 40 to 75%. Cambodge is used as a pigment in the manufacture of lacquer and in medicine.[22,29]

18.5 Functional properties

Garcinia fruit such as kokam and cambodge contains (-)hydroxycitric acid chemically similar to the citric acid found in oranges. One of the factors for fat accumulation in the body is increased quantities of the key enzyme known as ATP citrate lyase which facilitates the process of conversion of carbohydrates and sugar into fats and cholesterol. The fruit extract of *Garcinia cambogia* (containing 50% HCA as the chief ingredient) competitively blocks ATP citrate lyase enzyme making it ineffective which in turn

hinders the production and storage of body fats. By inhibiting this enzyme the fruit extract shifts the conversion of calories from fat to glycogen. This increased production of glycogen stimulates the glucoreceptors in the liver and sends satiety signals to the brain. Thus appetite and food craving are suppressed. Besides promoting glycogen production it also signals the Kreb's cycle to initiate beta oxidation which burns the body's stored fat. Thus the fruit extract containing highest concentrations of HCA promotes weight loss and assists the body's natural cycles in proper metabolism of fats.[4]

Research on hydroxycitric acid shows three benefits that should be of great interest to anyone concerned with weight management. It:

- decreases appetite
- inhibits the conversion of excess carbohydrates into fat
- increases stores of the body's energy fuel (glucose).

Extract containing HCA has proven its strength to reduce fat synthesis in the body from 40 to 70%. Garcinia fruit lowers blood lipids such as cholesterol and triglycerides by triggering fatty acid oxidation in the liver via thermogenesis (raising body temperature to speed up the body's metabolism which increases burning of fats). It burns the fat slowly and gently without stimulating the central nervous system. It also blocks the enzymes responsible for storing fat in our body from glucose. It mobilizes the body's fat stores and dissolves fat in the liver and throughout the body. It paves the way for slower weight loss and supports the body's natural appetite suppression mechanism. In addition it promotes the growth of lean muscles and also it is safe for diabetics.[30] The extract from the rind forms a major ingredient in herbal medicines. A variety of HCA products both in liquid form and salt of acid form is available in the market. 'Citrin' and 'Nature's Own' are popular products, which consists of calcium salt of (-)HCA and the recommended dosage is 250 to 500 mg after meals, three times a day. Among the gum resins cambodge, may be mentioned as containing α, β and γ-garcinolic acids. An essential oil was found to consist of terpene and camphor.

The kokam fruit is used in the Ayurveda system of medicine. The syrup prepared from the fruit is used in bilious infection.[21,31] The oil of the seed is much used for the preparation of ointments, suppositories and for other pharmaceutical purposes. It has been used as a local application to ulcerations, fissures of the lips, hands, etc., by partly melting it and rubbing on the affected part.[2,21,22,31] Oil from seeds is used as a remedy in 'Phthisis–Pulmonalis', scrofulous diseases, dysentery, mucous diarrhoea and as a substitute for spermaceti.[29] The oil is used as a healing application and from its powerfully absorbing heat it might be usefully employed in such wounds or sores as are accompanied with inflammation. The bark and root is astringent and the young leaves are used as a remedy for dysentery.[21]

18.6 Quality issues

Cambogin, a toxic resin, has been obtained from Garcinia.[31] This requires further investigation. The structure of cambogin has been given by Rastogi and Mehrotra[32] (Fig. 18.2). Muthulakshmi[7] compared the different methods of drying, viz. smoke drying, sun drying and oven drying. It was found that smoke drying recorded maximum rind recovery (24.3%), highest total acidity (21.33%) and (-)-HCA content (18.90%). The rind obtained by this method was soft, flexible and dark black in colour. The rind was superior in appearance and retained the original shape of the rind. By sun drying the rind recovery was

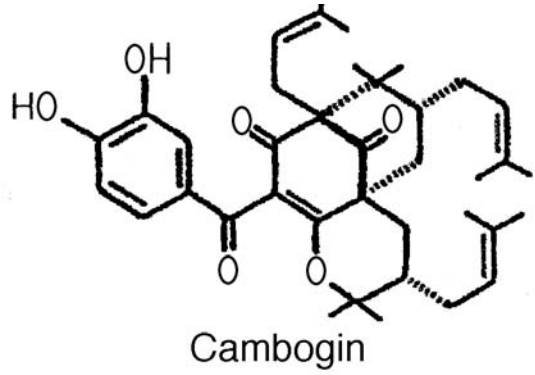

Fig 18.2

intermediate in texture with pale brown colour and shape retention was also intermediate. Oven drying recorded minimum values for rind recovery (21.59%), total acidity 19.72%, (-)HCA content 17.1%, rind texture was hard and brittle with brown colour. By oven drying the rind could not retain the rind shape and showed shrunken appearance.

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19

Marjoram

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19.1 Introduction

Sweet marjoram (*Majorana hortensis* (M.)) of the Labiatae family, is indigenous to Mediterranean countries and was known to the ancient Egyptians, Greeks and Romans (Tainter and Grenis, 1993). They cultivated it as a pot herb and used it not only to flavour food but also prized it as a miraculous herb with the power to heal practically all diseases, especially colds and chills. The Greeks felt it a symbol of happiness and that if grown on the grave, the deceased would be eternally happy. Hemphill and Hemphill (1984) mentioned that marjoram was one of the strewing herbs once used to give houses a pleasant, clean smell, and it was a favourite in sweet bags for the linen cupboard. Marjoram was popular during the Middle Ages as a medicine and as a culinary herb in England during the sixteenth century.

Now marjoram is grown in central Germany, Hungary, southern France and in the USA. It is also grown in western Asia, South and North America, France, Spain, Portugal, the UK, North Africa, Morocco, Tunisia, China, Russia and India. For many years both marjoram and oregano were known as *Origanum majorana* L. Today marjoram is identified as *Majorana hortensis* as a member of the mint family (Pruthi, 1976; El-Keltawi and Khalil, 1986; Kybal and Kaplicka, 1990; Prakash, 1990). It has often been mistaken for oregano in botanical description (Tainter and Grenis, 1993).

According to Pruthi (1976) it is the dried leaves of marjoram or sweet marjoram with or without flowering tops in small proportions that constitute the spice of commerce. It is an aromatic herb of the mint family and grows to a height of 30 to 60 cm. The herb develops a large number of leafy stalks with small leaves. The leaves are whole and the large ones are always fragmented. Leaves are light, greyish green and oblate to broadly elliptical, margin entire, reaching about 21 mm in length and 11 mm breadth (Parry, 1969). The flowers are small, white or pinkish or red. Essential oil is very strong and of very pleasant fragrance. The highest percentage is found in the leaves, whereas only traces are found in flowers and stalks. Long periods of blooming encourage the accumulation of oil in seeds (Guenther, 1974).

Sweet marjoram is characterized by a strong spicy and pleasant odour. The flavour is fragrant, spicy, slightly sharp, bitterish and camphoraceous. Though a perennial, it is treated as an annual under cultivation. The colour of the dried herb is light green with a slight greyish tint. The whole leaves are small with hairs on both sides of the leaf. When examined under the low power of a microscope, many dot-sized oil glands are seen on the leaf. They yield 3.5% volatile oil (Pruthi, 1976).

The colourless oil is obtained from the whole plant, including the square stem, the long leaves, and the white labiated blossoms. The scent is reminiscent of a mixture of lemon and lavender. What is most striking about marjoram is that it has an anaphrodisiac effect, yet in spite of this, it is fragrantly employed in the production of perfumes (Junemann, 1997).

Marjoram is known by the following names:

- English: Marjoram
- French: Marjolaine
- German: Majoran
- Italian: Maggiorana
- Spanish: Mejorana

19.1.2 Other species

Wild marjoram

Wild marjoram (*Origanum vulgare*) is a perennial herb native to Europe and West Asia and is commonly found in dry places and as hedge banks in England and has been naturalized in the United States.

Pot marjoram

This is also a Mediterranean plant growing to about 30 cm in height. Pot marjoram is cultivated for its aromatic leaves and is used for flavouring food. The plant is not very hardy and produces white flowers. Its taste is slightly bitter and can be used to some extent for the same purpose as sweet marjoram especially in strong flavoured dishes as with onion, wine and garlic, where the delicate perfume of sweet marjoram would, in any case, be largely lost. In Greece there are no fewer than ten different species of origanum growing wild and they are commonly known as *rigani.* One of these, known as winter marjoram (*Origanum heraclesticum*) is sometimes cultivated in gardens. Other species are *Origanum smyrnaicum* and *Origanum paniflorum*. *Rigani* are used with grilled meats and other Greek dishes, but it is almost impossible at present to buy the authentic herb and reproduce exactly the flavour of such dishes outside that country. Another species of origanum commonly known as certain dittany is cultivated particularly on the island of Crete (it is known as *dictamo, ditamo, eronatus, stomatochorto* and *malliaro-chorto*) and is used mainly for medicinal purposes though also as a food flavouring.

19.2 Harvesting and post-harvest management

19.2.1 Harvesting

Marjoram grown in Egypt is harvested from March to July. French marjoram is harvested in September to November. Guenther (1974) mentioned that if marjoram is harvested prior to seed formation, the leaves usurp the volatiles. Kybal and Kaplicka (1990) opined

that the herb might be harvested and dried in early summer before flowering. The foliage is cut off about 6 cm above the ground and it will put out new shoots and yield another crop in autumn. According to Prakash (1990) the first harvest of the leaves and tender tops of the herb is done as flowering commences. The plants are cut 5 to 8 cm above ground level and, with favourable conditions, a second cutting may be made two months later. In North Europe marjoram is usually replanted annually. Aharoni *et al*. (1993) have pointed out that young fresh green marjoram becomes a highly perishable produce due to senescence-accelerated metabolism accompanied by loss of freshness, chlorophyll and culinary quality and hence post-harvest management is necessary.

Omer *et al*. (1994) studied the effect of harvesting periods on the essential oil of marjoram in newly reclaimed lands of Egypt. It was observed that though the best yields of herb, leaves and oil were obtained from the second and third harvest of each season, the oil content of leaves was lower in the second year. Usually only one cut of marjoram can be made in a growth period. However, in years with favourable climatic conditions, a second and third cut may be made, although plants in these cuts reach only a pre-flowering stage. The influence of successive cuts on intrinsic quality characteristics and post-harvest behaviour are of special interest. Bottcher *et al*. (1999) in Germany observed that freshly harvested marjoram, though having a slightly woody stem, was characterized by an unusually high respiration rate and it was maintained throughout the post-harvest period of 72 to 80 h. The greatest decrease in the rates occurred during the first 18 h after cutting. The essential oil balance measured over the post-harvest period increased slightly (10%). Even 72 to 80 h after harvest, at 10ºC the plant material was maintained in a fresh green state, whereas at 20 and 30ºC degradation was accelerated due to the onset of senescence. They observed that at 20ºC, the acceptable marjoram quality after harvest could be maintained for only 48 h. A uniform deep green colour and an excellent anatomical appearance (without signs of wilt) were best maintained, as in dried material, when the herbs were kept at 10ºC throughout the post-harvest period.

Essential oils and their composition are the most important characteristics that determine the economic value of marjoram as an aromatic plant. They further noticed that these characteristics did not decline in spite of the high respiration rate, but were relatively stable under the chosen post-harvest conditions between 10 and 30ºC for 72 h. At 30ºC, first harvesting at the optimal stage (10 to 30% flowering) gave a higher essential oil (22%) than freshly harvested dried material, but physiologically younger plants (second cut) even showed a 35% increase. In some cases the proportion of *cis*-sabinenic hydrate and sabinenic hydrate-acetate increased slightly at 20ºC and 30ºC while there was only a minor influence on α- and β-terpinenes and 4-terpineol. They have opined that respiration energy is involved actively in synthesis of essential oil in plant tissue and that the high respiration rate has to be considered in the development of future equipment and technologies for ventilating, cooling and drying during the post-harvest period.

19.2.2 Post-harvest drying and storage

After the harvest the leaves are dried, carefully cleaned and stored. Methods of drying depend on the size of the crop and climatic conditions in the producing countries. Cut plants may be tied as bunches in small quantities and dried in the open air or spread on wire trays in ventilated rooms and dried by regulated circulation of warm air. Sun drying may take two to four days for drying and in the case of ventilating drying sheds it may take more than a week. Stems or stalks are separated from leaves by rubbing on hand

sieves of 1 to 2 cm mesh. Chaff is removed by using a fan and extraneous sand, earth and dust are removed by shaking in wide-meshed sacks (Guenther, 1974). More recently in Egypt the harvested material is pre-dried in the field and then in a solar drier to reduce the microbial load to less than 50% in comparison with the traditionally dried material.

Buckenhuskes *et al*. (1996) used a solar greenhouse drying system for marjoram in Egypt and found that the shoot essential oil content after drying was 98% of the initial value. Microbial load could also be reduced considerably by this improved method. Singh *et al*. (1996) found that microwave blanching of marjoram gave the maximum retention of ascorbic acid (21.5% which is 79.4% of the composition of fresh herb). Blanching resulted in better retention of the original green colour of the fresh herb compared to direct drying of the herb. The herb had firmer texture when microwave blanched than when blanched by other methods and when fresh.

Paakkonen *et al*. (1990), while studying the effect of drying, packing and storage on quality of herbs, found that odour and taste of freeze-dried marjorams were sensitive to storage conditions. Freeze-dried marjoram exhibited a much more intensive colour than air-dried marjoram. After nine months of storage in the light or raised temperature, the colour tone of the freeze-dried marjoram had changed only slightly. They could not notice any significant difference in odour and taste intensities for the frozen and air-dried products after eight months of storage, whereas the taste of the freeze-dried marjoram differed from the marjoram stored frozen. The intensity of the odour and taste of the air-dried marjoram stored under vacuum was higher relative to the marjoram in glass jars or paper bags. An elevated storage temperature of 35º C was found to have a more detrimental effect on sensory quality than packaging. It was concluded that the intensity of odour and taste of dried herbs could be maintained for two years at 23ºC in airtight packaging.

Malmsten *et al*. (1991) demonstrated that freeze-drying was more effective than air-drying as a means of preserving the herb and also for microbial decontamination. Raghavan *et al*. (1997) noticed that convection drying at about 45ºC for 6 h preserved the flavour quality of marjoram to a greater extent than microwave drying.

19.2.3 Irradiation processing

Only limited information is available regarding irradiation of marjoram. Bachman and Gieszczynska (1973), while studying various aspects of irradiation of different spices including marjoram, noticed that irradiation at 7.5 to 12.5 kGy produced a change in flavour of marjoram. Frag *et al*. (1995) evaluated the effect of irradiation on microbial loads of herbal spices and found that irradiation at 10, 20 and 30 kGy caused complete elimination of microorganisms whereas 5 kGy was less effective. They observed a noticeable reduction in the amounts of terpenes present in irradiated marjoram, which were converted to monoterpenes alcohols. The results proved that 10 kGy was a sufficiently high dose to eliminate the microorganisms, causing only slight changes in the flavouring materials.

19.3 Essential oil

Sweet marjoram essential oil, known in the trade as 'Oil of sweet Marjoram', is obtained by steam distillation of the dried leaves and the flowering tops of the herb yielding 0.3 to 0.4% oil from fresh and 0. 7 to 3.5% from dry herb. It is a pale yellow or pale amber

coloured rather mobile liquid (Shankaracharya and Natarajan, 1971; Farrell, 1985). Dayal and Purohit (1971) obtained 0.8% essential oil from marjoram seeds, which was also a pale yellow mobile liquid with a characteristic smell. Considerable variations in the compositional pattern are observed depending on the origin of herb, climatic and drying conditions, production procedure of the oil and many other factors. The aroma and taste are spicy, fragrant, warm, aromatic, penetrating and resemble that of lavender. The taste has a slightly bitter aftertaste.

19.3.1 Composition

Many investigators have made studies on the composition of essential oil of marjoram and the important findings have been compiled by Lawrence (1981, 1983, 1984, 1989, 1997) and Prakash (1990). Verghese (2000) has reported the following types of compounds in sweet marjoram.

1. Monoterpenes: terpinolene, β-phellandrene, α-terpinene, γ-terpinene limonene, sabinene, α-thujene, α-pinene, β-pinene, camphene, myrcene, ocimene
2. Monoterpene alcohols: linalool, geraniol, α-terpineol, terpinene-4-ol, *cis*- and *trans*-2-p-menthen-1-ol, *cis*- and *trans*-sabinene hydrate, *cis*- and *trans*-piperitol, borneol, p-cymene-8-ol
3. Monoterpene carbonyls: carvone, α-thujone, camphor
4. Monoterpene esters: neral acetate, geranyl acetate, linalyl acetate, and terpenyl-4-acetate
5. Sesquiterpenes: β-caryophyllene, α-humulene, α-copaene, farnesene, ledene, γ-elemene, β-bisabolene, bicyclogermacrene, allo-aromadendrane
6. Terpinoid ether/oxides: 1,8-cineol, aryophyllene epoxide
7. Benzoid compounds: p-cymene, eugenol, thymol, carvacrol, methyl chavicol, anethole.

Subramanian *et al*. (1972) studied the polyphenols of the leaves of marjoram and a new flavone designated majoranin, shown to be 4′,5,7-trihydroxy-3′,6,8-trimethoxyl flavone and the 7-glucuronides of dinatin and diosmetin have been isolated. Salehian and Netien (1973) compared major components of French, Hungarian and Egyptian marjoram essential oils and found that the ratio between the percentage composition of terpinen-4-ol to linalool and linalyl acetate decreased in the order Hungarian, French and Egyptian marjoram.

Study on marjoram by Taskinen (1974) from Bulgaria and Turkey by distillation with steam and by extraction and distillation with alcohol-water mixture disclosed 53 compounds. The amount of monoterpene alcohols in the alcoholic distillate was only around 20% compared to about 60% in the steam distillate. Granger *et al*. (1975) reported that oil existed in two forms, one predominant in *cis*-sabinene hydrate (*cis*-thujanol) and the other in terpinen-4-ol. They suggested that these two compounds could be thought of as being biogenetically related and the chemical composition of various marjoram oils as quantitative variations on a central biosynthetic theme. In addition to these compounds, ten monoterpene hydrocarbons, five oxygenated compounds and two sesquiterpene hydrocarbons were also isolated and identified.

Karawya and Hifnawy (1976) reported the chemical composition of essential oil of marjoram from Egypt. Sarer *et al*. (1982) found that the oil of marjoram from Turkey contained monoterpene hydrocarbons, oxygenated monoterpenes and phenols. Ramachandraiah *et al*. (1984) reported the physico-chemical characteristics of Indian

Sweet marjoram oil from dried leaves. In a study by El-Keltawi and Khalil (1986) the highest percentage of essential oil in Egypt was recorded by applying 50 ppm of 2-styryl cyanine.

Nykanen (1986) identified a total of 56 compounds and the most prominent components were *cis*-sabinene hydrate and 4-terpineol. Later in 1987, Nykanen and Nykanen reported the composition of fresh and dried cultivated marjoram from Finland. While comparing the yield and other attributes of different forms of marjoram from various regions of USSR and abroad, Voronina (1988) found that the highest essential oil yield was 1.6% from Crimea, followed by 1.56% from Czechoslovakia. The oil yield was 1.52% and 1.20% for marjoram from Romania and Egypt respectively as reported by Refaat *et al*. (1990). Egyptian marjoram oil was richer in the main component, terpinen-4-ol (28.85%), in the first cut than the Romanian sample (20.80%).

Franz (1990) from Austria confirmed the importance of *cis*-sabinene hydrate and other compounds in giving the characteristic flavour of marjoram leaves. The essential oil composition of different lines of marjoram grown in Turkey was analysed by Kiryaman and Ceylan (1990) and it was found that linalool content ranged from 17.53 to 48.05% and carvacrol content from 7.34 to 38.42%. Yadava and Saini (1991b) reported 18 components of essential oil of marjoram and their percentages varied from 2.84 to 36.7. There was one unidentified compound whose concentration was 1.10%. Karwowska and Kostrzewa (1991) noticed that essential oil of marjoram grown in Poland had no identical analogue, and the nearest in composition was essential oil from marjoram grown in Egypt.

Komatis *et al*. (1992) studied the composition of essential oil of marjoram in Greece. Gas chromatographic analysis revealed 65 compounds. The most prominent component was 4-terpineol (37%) and together with α-terpineol and *cis*- and *trans*-sabinene hydrate, constituted 50% of the essential oil. Three substances, viz., santalol, verbenone and carvacrol, were identified for the first time in marjoram. Pino *et al*. (1997) analysed the essential oil of marjoram grown in Cuba and found that among the 41 compounds identified, terpinen-4-ol (17.6%), linalool (16.41%) and thymol (11.55%) were the main constituents.

Croteau (1977) studied the site of monoterpene biosynthesis in the leaves of marjoram. Excised epidermis of marjoram leaves incorporates label from (U-^{14}C) sucrose into monoterpenes as efficiently as leaf discs, while mesophyll tissue has only a very limited capacity to synthesize monoterpenes from exogenous sucrose. These results strongly suggest that epidermal cells, presumably the epidermal oil glands, are the primary sites of monoterpene biosynthesis in marjoram.

Khanna *et al*. (1985) obtained 1.9 per cent of oil for marjoram grown in saline alkali soils (pH 9.0 to 10.5). The main constituents identified by them were α-terpinene, peymene, geraniol, linalool, α-terpineol, carvacrol and thymol. El-Bilay (1985) noticed that young leaves of marjoram contained high levels of terpinen-4-ol, whereas aged leaves contained high levels of *cis*-sabinene hydrate. The young leaves had an appreciably greater capacity to synthesize volatile oil than aged leaves. Although oil glands were not the centres of monoterpene biosynthesis, it was suggested that they are the main stores of terpenes in the plant. Fischer *et al*. (1987) demonstrated that *cis*-sabinene hydrate and its acetate represent the original flavour compounds of the intact leaf. They opined that most of the monoterpenes described in the literature as being components of marjoram oil appear to be artifacts.

Arnold *et al*. (1993) observed marjoram flowers to be richest in essential oil. They could identify 39 components, of which *cis*-sabinene hydrate (7.4 to 33.3%) and terpinen-

4-ol (16.6 to 21.6%) were characteristic of *Origanum majorana* var. *tennifolium*, while the main compound in *O. dubium* was carvacrol (81%). Carvacrol (69.4 to 81.6%) was also the major constituent of *O. onites.* Omer *et al.* (1994) identified nine components from the essential oils, and although there were qualitative and quantitative differences, the main constituent of all oils was terpinen-4-ol (26.7 to 41.6%).

Cis-sabinene hydrate, the main component of essential oil of marjoram, a long-day plant (Circella *et al.*, 1995) was produced in larger quantities in plants grown under 16 h light conditions than under conditions of 13 h and 10 h. However, terpinenes decreased with increasing day length. They opined that this effect on oil composition appeared as a reflection of the growth and development stage of the plants under the different photoperiods. Lower (older) leaves contained an essential oil with a relatively higher terpinene concentration. The essential oil composition of the inflorescences was found to be different from that of the leaf oils. The inflorescences were richer in sabinene and linalyl acetate, but poorer in *cis*-sabinene hydrate and α-terpinene. As *cis*-sabinene hydrate is considered to be the key component for the typical marjoram flavour and fragrance (Fischer *et al*., 1987), the photoperiod influences the quality of marjoram to some extent. This explains partly why marjoram grown in northern environments is sensorally preferred.

Studies by Rahgavan *et al.* (1997) of hydrosteam distillation analysis revealed that fresh marjoram volatiles contained 95 to 97% monoterpenes and their derivatives and 3 to 5% sesquiterpenes. They observed that *cis*-sabinene hydrate; *trans*-sabinene hydrate and terpinen-4-ol were the major components responsible for the characteristic flavour of the herb. Indian marjoram contained more *cis*-sabinene hydrate (23.6%) than any other sample referred to in the literature and this compound was retained in the convection and microwave (175 W) dried samples to a great extent. Rupasova *et al*. (1998) observed changes in biochemical composition of marjoram upon introduction in Belarus. Harvesting at the full flowering stage gave the highest yield of active compounds compared to the vegetative or budding phase. Molina *et al*. (1999) from northwest Argentina reported an essential oil content of 0.28 to 1.55% on fw basis. Vera and Chane-Ming (1999) from Reunion Islands observed that the essential oil was rich in terpinen-4-ol, *cis*-sabinene hydrate, *p*-cymene and γ-terpinene together with sabinene, α-terpineol and α-terpinene. They constituted about 80% of the total essential oil. Ozguven and Tansi (1999), in Turkey, obtained the highest essential oil yield at the post-flowering period. The main components of the oil were γ-terpinene, p-cymol and terpineol.

19.3.2 Extraction

The steam distillable essential oil gives the subtle and delicate flavour of marjoram (Raghavan *et al*., 1997). Fischer *et al*. (1987) opined that carefully controlled extraction of flavour using supercritical carbon dioxide could maximize the content of *cis*-sabinene hydrate and minimize that of terpinen-4-ol. The formation of rearranged monoterpenes in essential oil of marjoram was due to two activated forms, viz. Z-sabinene hydrate pyrophosphate, Z-sabinene hydrate acetate along with Z-sabinene hydrate (Fischer *et al.*, 1988). Ikeda *et al*. (1962) used retention time data to characterize the hydrocarbons (36.4% of the oil) found in sweet marjoram.

Jimenez-Carmona *et al*. (1999) made comparisons of marjoram oil by continuous subcritical water extraction (CSWE) of ground marjoram leaves (0.4 g) by subjecting them to dynamic extraction with water at 50 bar, 150ºC and 2 ml/min for 15 min. and hydrodistillation of 140 g of marjoram leaves with 1000 ml of water for three hours. It

was found that when CSWE was used, the compounds were removed from the aqueous extract by a single extraction with 5 ml of hexane, detected by gas chromatography-flame ionization detection (GC-FID) and identified by mass spectrometry, electronic impact. The CSWE method was quicker (15 min. vs 3 h), provided a more valuable essential oil (with higher amounts of oxygenated compounds and no significant presence of terpenes) and allowed substantial savings on cost, in terms of both energy and plant material. The efficiency, in terms of volume of essential oil/l g of plant material, of CSWE is 5.1 times higher than that provided by hydrodistillation.

19.4 Use in food

Marjoram is used in many foods where a well-rounded herb note is desired. Nowadays, marjoram is added to soups, salad dressings, sauces for stewed meats (mainly mutton) and stuffings. Its widest use, however, is in seasoning sausages and salamis. Sometimes it is used together with other fresh herbs in 'bouquet garni'. It has been used as a substitute for oregano when prices for that spice go up. Marjoram can be added to practically any dish in which one would use thyme (Stobart, 1970). Marjoram has a delicate perfume, which can be lost easily while cooking. Hence it is at its best when added shortly before the end of cooking or used in dishes which are cooked very little, such as an omelet. It may also be used raw and it is particularly delicious when finely chopped and with lemon juice.

Pruthi (1976) reported that fresh leaves are employed as garnish and incorporated in salads. Dried flowering tops are used for sachets and potpourri. The aromatic seeds are used in confectionery and French confitures. Marjoram has pleasantly aromatic and distinctly mint-sweet flavour with slightly bitter undertones (Anon., 1989). This subtle aroma makes it an ideal addition to many herb mixtures as it helps give 'body' and depth to a variety of dishes. Kybal and Kaplicka (1990) mentioned that marjoram was used in brewing beer before hops were known, and in France for making a wine called 'hippocras'. It was also added to water used to rinse the fingers at the table during banquets. They also reported that marjoram is used more often in western cooking than in eastern cooking and finds more use in the UK, Germany and Italy. They described the use of marjoram according to ingredient, cooking technique and use for flavouring plant or animal food. Marjoram is used in Italian herb blends and is often a component of pizza and spaghetti sauce mixes. It is used in the whole and ground form and to a limited extent as an essential oil or oleoresin. The dried leaves and floral tops are superb for seasoning all meats, poultry, sea food and baked or grilled fish, egg and tomato dishes, soups such as chicken, mutton, turtle, green vegetables, stews, fruit salads, in flavouring vinegar; in formulation of liqueurs, vermouths. Seed of sweet marjoram finds use in meat products and confectioneries and French confitures make use of its oil.

According to Chiej (1984), sweet marjoram oil is used for flavouring of fats, oils, baked foods, coconut foods, meat products, processed vegetables, condiment relishes, soups, vinegars, snack food and gravies. It is also employed in perfumery to introduce a fresh slightly medicinal-aromatic warm note and in medicinal formulations. Hirasa and Takemasa (1998) mentioned use of marjoram in a ground herb blend, which goes well with poultry flavoured foods. Italian sauce contains marjoram with other spices such as onion, oregano, basil, fennel, black pepper, red pepper if heat is desired, and possibly thyme. Greek cuisine uses oregano and marjoram frequently.

Biacs and Wissgott (1997) noticed that addition of 0.2% (w/w) of marjoram and rosemary could reduce the pigment degradation in tomato products during storage. Dried marjoram gave one of the most efficient protections in light. During the frozen storage marjoram also gave protection against oxidation. The fresh marjoram protected the carotenoid pigment to a lesser extent than dried marjoram, which could be due to the high dry matter content of dried and the high water content of fresh marjoram. After nine weeks of storage the total carotenoid content loss was least in the case of fresh and dried rosemary and dried marjoram (20 to 28%).

Shaaya *et al*. (1991) analysed the fumigant toxicity of 28 essential oils extracted from various spice and herb plants and some of their major constituents, were assessed against four major stored-product insects. The results showed that the compound linalool, α-terpineol and carvacrol and the essential oils of oregano, basil, Syrian marjoram and thyme were most active against *Oryzaephilus surinamensis.*

19.4.1 Other uses

Studies were made by Kraus (1990, 1992), Quedzuweit (1994), Long *et al*. (1997) and Long and Long (1998) on the control of *Varroa jacobsoni* infestation in bees. Though Quedzuweit could not get any successful control under a simulated field condition, the other workers observed control of varroasis of honey bees (*Apis mellifera*) using formic acid and marjoram oil. Chiej (1984) reported the use of sweet marjoram for disinfesting beehives.

Osmani *et al*. (1978) studied the effect of marjoram oil on metamorphosis of *Aedes aegypti* and found that though oil of marjoram is a poor inhibitor of growth at early larval stages, the fourth stage larvae, when treated with 60 or 80 ppm, produced either malformed pupae or malformed adults which were found to be dead within the pupal cases. The oil partially arrested the normal development of mosquito and is a good larvicide.

El-Maksoud *et al*. (1999) observed that the highest weight gain of fingerlings of Nile tilapia (*Oreochromis niloticus*) was obtained when they were fed with 3% marjoram leaves of the total diet. This also resulted in the best protein and energy utilizations apart from having a significant effect on body composition. Marjoram oil is also employed to a small extent in high grade flavour preparations and perfumes and in the soap and liquor industries (Pruthi, 1976).

19.5 Functional properties

Essential oils from aromatic and medicinal plants have been known since antiquity to possess biological activity, notably antibacterial, antifungal as well as antioxidant properties (Tiziana and Dorman, 1998). With the increasing interest in the use of essential oil in both the food and the pharmaceutical industries, a systematic evaluation of plant extracts for these properties has become increasingly important. Bacterial and fungal infections pose greater threats to health and hence the use of natural antimicrobial compounds is important in the control of human and plant diseases of microbial origin.

19.5.1 Antimicrobial properties

Yadava and Saini (1991a) studied the antimicrobial effect of marjoram and found that fungi which were inhibited are *A. fumigatus* and *A. niger.* Studies by Ueda *et al*. (1982)

revealed that the Minimum Inhibitory Concentration (MIC) required for fungi such as *S. cerevisiae, C. paracrusei, C. krusei* and *A. oryzae* was <4.0%. Tiziana and Dorman (1998) reported antifungal activity of marjoram oil against the common spoilage fungus *Aspergillus niger* (strain IMI 17454) even at concentration of 1 micro litre/ml broth.

Huhtanen (1980) observed that the MIC of hexane extract of marjoram needed for control of bacteria such as *E. coli*, *Salmonella* sp., *S. aureus, B. cereus* and *Campylobacter* was 10% while Ueda *et al*. (1982) reported that only a lower concentration of 4% was necessary for control of bacteria such as *Bacillus subtilis, S. aureus 209P, E. coli, S. tphimurium, S. marcescens, P. aeruginosa, P. vulgaris* and *P. morganii* at pH levels of 5 or 7. *B. subtilis* and *S. aureus* were the most vulnerable and at pH 5.0 the MIC for these two bacteria were 0.5 and 0.2% respectively. The antibacterial effect of marjoram oil was reported by many other workers (Galli *et al*., 1985; Deans and Ritchie, 1987; Deans and Svoboda, 1990; Yadav and Saini, 1991a). Tiziana and Dorman (1998) noticed that marjoram oil was most active in inhibiting the growth of *Acinobacter calcoacetica*, *Beueckea natriegens* and *Staphylococcus aureus*. However, Deans and Svoboda (1990) noticed marjoram oil to be least effective against *S. aureus*, which is a food poisoning bacterium.

19.5.2 Antioxidant properties

The discovery of inhibition of lipid oxidation by some phenolic compounds during the late 1940s has contributed to the application of synthetic antioxidants in the food industry (Dapkevicius *et al*., 1997). Widely used artificial antioxidants such as butylated hydroxytoluene (BHT), and butylated hydroxyanisole (BHA) (Chan, 1987) are very effective in their role. However, their use in food products has been falling off due to their instability, strict legislation on the use of synthetic food additives, as well as due to a suspected action as promoters of carcinogenesis (Namiki, 1990; Pokorny, 1991; Duh and Yen, 1997). For these reasons there is a growing interest in the study of natural additives as potential antioxidants. The antioxidant properties of many herbs and spices are reported to be effective in retarding the process of lipid peroxidation in oils and fatty acids and have gained interest of many research groups. Shahidi *et al*. (1992) and Madsen *et al.* (1997) suggested that the antioxidant effect of aromatic herbs is due to the presence of hydroxy groups in their phenolic compounds. Tsimidou and Boskou (1994) concluded that among the herbs and spices extensively studied, the plants obtained from the Lamiaceae (Labiatae) family possess a significant antioxidant activity.

Some natural polyphenols have therapeutic effects or a protective action against cardiovascular diseases and some cancers (Heinonen *et al*., 1998) and their use as a means of increasing the shelf-life of food products, improving the stability of fats and oils rich in polyunsaturated fatty acids (PUFAs), in slowing down the ageing process and in the treatment of human diseases such as atherosclerosis and cancer was also reported (Tiziana and Dorman, 1998). They observed that in egg yolk assay, the antioxidant activity of marjoram was much higher than that of α-tocopherol and comparable with that of BHT at all concentrations tested (100 to 1000 ppm).

Saito *et al*. (1976) have obtained a higher antioxidant activity of marjoram at 0.02% against lard than tocopherol. Similar reports of effectiveness of marjoram as an antioxidant are available from other workers (Dapkevicius *et al*., 1997; Trombetta *et al*., 1998). Biacs and Wissgott (1997) noticed that ground tomato seeds with rosemary and marjoram stabilized the carotenoid pigments by way of their antioxidizing power. El-Alim *et al*. (1999) studied the effect of different dried spices and noticed that utilization

of spices such as marjoram, wild marjoram and caraway and their mixtures or extracts in semi-prepared meat products intended to be frozen for up to six months or more before consumption is proved to be advantageous in regard to shelf-life of the food as well as for human health.

Even though many workers noticed favourable antioxidant effect of marjoram as described above, Baardseth (1989) could not replace the antioxidant BHA in potato flakes production if stored for up to 24 months by others like TBHQ, α-tocopherol, Prolong P (rosemary, thyme, marjoram mixture) or ascorbyl palmitate. Economou *et al.* (1991) found that marjoram extract was much less effective as an antioxidant than rosemary or oregano extract.

19.5.3 Control of platelet aggregation

Okazaki *et al*. (1998) investigated the inhibitory effect of methanol extracts of 20 herbal species on human platelet aggregation, a factor in conditions such as thrombosis. Allspice, basil, marjoram, tarragon and thyme strongly inhibited the platelet aggregation induced by collagen. Basil, marjoram and tarragon strongly inhibited platelet aggregation induced by ADP. They isolated an active compound, arbutin, from sweet marjoram as an inhibitor of platelet aggregation.

19.5.4 Other therapeutic properties

Yamazaki (1995) studied the effect of both medicinal and edible herbs and plants of the Labaiatae family including marjoram against HIV. Though he found non-inhibitory action on HIV for 70% ethanol extract of marjoram, at a concentration of 31 μg/ml of water extract showed effects of inhibition of HIV-1 on Molt 4 (MT-4) cells. Formation of giant cell was also found to be inhibited by concentration of marjoram extract at 125 μg/ml. He suggested that the mechanism of their anti-HIV activity is due mainly to their inhibitory action on cell-to-cell adsorption.

Anderson *et al*. (2000) evaluated the effect of massage with essential oil on children with atopic eczema and found that aromatherapy massage is a good treatment for the control of atopic eczema.

Pruthi (1976) reported that intravenous injection of dogs with a saturated solution of essential oil in 33% ethyl alcohol (1 cc/kg body weight) increased peristaltic movement of intestine. Studies by Krukowski *et al*. (1998) in Poland have shown that mineral herbal supplements including nettle, St. John's wort, camomile, salvia, agrimony and marjoram tended to increase the immunoglobulin G (IgG) serum level of reared calves.

19.5.5 Uses in traditional medicine

Herbal medicines are being used by about 80% of the world population for primary health care and particularly in the developing countries. These drugs are popular for their safety, efficacy, and cultural acceptability as well as fewer side effects, and they cure age-related diseases for which modern medicines have not been completely successful. Ghos (2000) estimated that the herbal medicine market in Europe and America is worth ten and four billion US$ respectively.

Use of marjoram in medicinal preparations was in vogue from many years back. Chopra *et al*. (1956) reported the use of marjoram oil in hot fomentations, for acute diarrhoea, and as an expectorant. Parry (1969) described marjoram to have properties of

antiseptic, antispasmodic, carminative, stimulant, expectorant and nerve tonic. It functions as cure for asthma, coughs, indigestion, rheumatism, toothache and heart conditions. According to Mabey (1988) marjoram contains tonic and astringent bitter principles, which rouse the appetite and hence it is helpful for invalids.

The leaves and seeds of marjoram are considered as astringent and a remedy for colic (Dayal and Purohit, 1971). Chiej (1984) reported that the powder acts as a sternulatory (inducing sneezing) if inhaled, and is, therefore effective against head colds. Prakash (1990) mentioned the use of volatile oil as an aromatic stimulant in colic, dyspepsia, flatulence and dysmenorrhoea.

Sweet marjoram appears to have a stronger effect on the nervous system than its wild cousin (Balz, 1999; Chevallier, 1996). Sweet marjoram is a good general tonic, helping to relieve anxiety, headaches and insomnia. The herb is also thought to reduce sexual desire (Mahindru, 1994). Junemann (1997) mentioned that marjoram oil relaxes and alleviates tension, both mental and physical, and is used in natural healing for many complaints accompanying or caused by tension. Guba Ron (2000) reported that essential oil of marjoram has menstrual-regulating or hormone-like effects.

19.6 Quality issues

19.6.1 Quality control and adulteration

As the vegetative parts of marjoram are used in the food and pharmaceutical industries, maintenance of quality of the produce is of utmost importance right from the harvesting stage onwards. All possible means should be taken to eliminate any chance of physical or microbial contamination.

El-Kady *et al*. (1995) highlighted the importance of quality control to prevent growth of fungi and bacteria in food products. They analysed 120 samples belonging to 24 kinds of spices collected from different places at Assuit Governorate (Egypt) for the natural occurrence of mycotoxins and reported for the first time the presence of aflatoxins (8–35 μg/kg) and sterigmatocystin (10–23 μg/kg) in different samples including marjoram. However, they could not detect the presence of ochratoxin and zearalenone.

Glaze (1976) developed an improved method for extraction of light filth from whole, cracked, or flaked spices including marjoram. It involves a chloroform or isopropanol defatting, followed by a direct flotation from 40% isopropanol with Tween 80-EDTA (1+1) and mineral oil-heptane (85+15). The results showed that the proposed method is more rapid to perform and helps in better recoveries of filth than the official first action method for ground spices. Subsequently, Dent and Glaze (1985) mentioned that the present method for separating filth in underground marjoram is conducted in two steps, the first of these, which is for heavy filth and sand, requires the spice to be boiled with petroleum ether, then floated off with chloroform and, if needed, carbon tetrachloride. The second step, which is for light filth, is dependent on completion of the heavy filth section. After the spice is air dried, the light filth is extracted with heptane and water. The proposed method was developed to make light filth independent of heavy filth analysis, to improve filth recovery, and to reduce microscopic examination time. The light filth is extracted by ethanol defatting followed by a combination of 115–60% ethanol/mineral oil extraction in a Wildman trap flask. The proposed method gave average recoveries of 73% for rodent hairs and 70% for insect fragments and it has been adopted as official first action to replace AOAC 13th edition sections 44.142 and 44.120(b) for underground marjoram only.

Ravid *et al*. (1987) developed a method for finding out the adulteration of natural marjoram oil with racemic synthetics. They found that the determination of the enentiomeric composition of natural terpinen-4-ol, which is the major constituent in the essential oil of the fresh leaves and flowers from sweet marjoram, linalool and linalyl acetate by H-NMR spectroscopy using a chiral lanthanide shift reagent is a fast and non-destructive method. With the help of the method developed, it could be possible to make quantitative detection of adulteration of essential oil with synthetic racemic alcohols and acetates. Tietz *et al.* (1991) standardized a flavour profile analysis method for the evaluation of carbon dioxide extracts of marjoram. The method used for the development of a high-pressure extraction is quite suitable for the characterization of marjoram extracts as well as for the evaluation of commercial marjoram samples for any possible adulteration.

Pank *et al*. (1999) suggested that an intensive green colour was typical of high quality in marjoram. They also observed a positive correlation between taste and smell. From another study Pank *et al*. (2000) opined that marjoram originated and processed in the northern region of the Harz Mountains and in the area of Madeburger Borde, Germany, has a high reputation in the world market due to its very high quality. They pointed out that the colour of the dried marjoram is of outstanding importance and a light green colour is preferred by consumers than a darker product.

19.6.2 Chemical and physical specifications

Marjoram should consist of the dried leaves, with or without a small portion of the flowering tops of *Majorana hortensis* Moench. According to Heath (1978) the odour should be fresh and sweetly aromatic, slightly floral, penetrating but not irritating, cooling and pleasantly green, herbaceous with soft woody, fruity back tones, lingering and does not change much on airing from a smelling strip. The flavour should be warm, spicy, herbaceous but not particularly green, slightly bitter but not unpleasantly so. Farrell (1985) suggested that the round, light green to grey-green leaves should possess a pleasant aromatic odour and have a warm, slightly bitter taste. The ground product shall contain not more than 10% of stems by weight; and it must be uniformly ground to allow for a minimum of 95% by weight, to pass through a US standard no. 30 sieve.

Various researchers have made analysis of quality parameters of dry herb and the results are summarized in Table 19.1. Wide variations are noticed in the mineral content of Indian, French and German sweet marjoram as reported in Table 19.2. Table 19.3 outlines the typical chemical and physical specifications, including FDA DALs. Table

Table 19.1 Analysis of dry herb

	Merory (1968)	Pruthi (1976)	Farrell (1985)
Water	—	7.0%	7.6g
Protein	14.5%	14.31%	12.7–14.3 g
Fixed oil	5.6%	5.60%	—
Volatile oil	—	1.72% in tops, 0.05% in stem)	—
Pentosans	7.68%	7.68%	7.68%
Fibre	—	22.06%	18–22 g
Ash	—	9.69%	12–13 g
Fat	—	—	5.6–7.0 g

Table 19.2 Mineral composition of marjoram from different sources (all values in per cent except for those given separately)

	Pruthi (1976)	Mahindru (1994)	Farrell (1985)	Winton & Winton (1939) German	French
Total ash	6.3–24	—	—	—	—
Sand	0.66–14	—	—	—	—
Sand-free ash	5.4–14.3	—	—	—	—
Potash	18.3–20.2	—	—	20.18	18.34
Sodium	0.65–0.68	0.65	77 mg	0.68	0.65
Iron	6.1–7.3	67000 ppm	83 mg	7.30	6.06
Calcium	17.6–24.8	21.2	1990 mg	16.70	24.80
Silica	19.4–26.5	—	—	—	—
Phosphorus	8.9–9.1	9.1	306 mg	8.88	9.10
Magnesium	4.8–6.7	57500 ppm	346 mg	4.76	6.74
Manganese	trace-1.05	—	—	—	—
Chlorine	1.51–2.05	—	—	2.05	1.51

19.4 gives the ESA specifications of quality minima of marjoram in whole form. Table 19.5 details the chemical and physical specifications of ground marjoram and the nutritional information is given in Table 19.6. Different workers have reported the physico-chemical properties of marjoram oil, which are presented in Table 19.7.

Table 19.3 Whole marjoram: chemical and physical specifications

Specification	Suggested limits
ASTA cleanliness specifications	
Whole dead insects, by count	3
Mammalian excreta, by mg/lb	1
Other excreta, by mg/lb	10.0
Mould, % by weight	1.00
Insect defiled/infested % by weight	1.00
Extraneous, % by weight	1.00
FDA DALs (6 subsamples)	
Insect infested and/or mouldy pieces by weight (unprocessed)	Av. of 5%
Mammalian excreta per lb. identified as to source when possible (unprocessed)	Av. of 1 mg
Insect fragments and/or rodent hairs (processed)	Av. of 250
per 10 g subsample (processed)	Av. of 2
Volatile oil	1.0% min
Moisture [1]	10.0% max
Ash	15.0% max
Acid insoluble ash	5.0 % max
Federal specification (EE-S-6311, 1981)	< 10% of stems by weight
Average bulk index (mg/100 g)	660

[1] ASTA suggested maximum moisture level.

Table 19.4 ESA specifications of quality minima (marjoram – whole form) – ISO

Ash (% w/w max)	10
Acid insoluble ash (% w/w max)	2
Water (% w/w max)	12
Volatile oil (% v/w min)	1

Table 19.5 Ground marjoram: chemical and physical specifications

Specification	Suggested limits
FDA DALs (6 subsamples)	
Insect fragments	Av. of 1175 or more/10 g
Rodent hairs	Av. of 8 or more/10 g
Volatile oil	0.8%
Moisture	10.0% max
Total ash	15.0% max
Acid insoluble ash	5.0% max
Military specifications (EE-S-631J, 1981)	
Volatile oil (ml/100 g)	0.6 min
Moisture	10.0% max
Total ash	15.0% max
Acid insoluble ash	4.0% max
Non-volatile ether extract	20–35
Granulation	95% min. through a U.S.S # 30
Bulk index[1] (ml/100 g)	270

[1] Average bulk index. Granulation will affect number.

Table 19.6 Nutritional composition of marjoram per 100 g

Composition	USDA Handbook 8-2[1]	ASTA[2]
Water (g)	7.64	6.5
Food energy (kcal)	271	365
Protein (g)	12.66	12.5
Fat (g)	7.04	6.8
Carbohydrate (g)	60.56	64.4
Ash (g)	12.10	9.7
Calcium (g)	1.990	2.5
Phosphorus (mg)	306	230
Sodium (mg)	77	110
Potassium (mg)	1522	1400
Iron (mg)	82.71	72.7
Thiamine (mg)	0.289	0.290
Riboflavin (mg)	0.316	0.320
Niacin (mg)	4.120	4.10
Ascorbic acid (mg)	51.43	51
Vitamin A activity (RE)	807	807

[1] Composition of Foods: Spices and Herbs. USDA Agricultural Handbook 8-2, January 1977.
[2] The Nutritional Composition of Spices. ASTA Research Committee, February 1977.

Table 19.7 Typical physico-chemical properties for the oil

Reference	Specific gravity	Optical rotation	Refractive index (220º)	Acid number	Ester number	Solubility
Guenther (1974)	0.892 to 0.901 (15º/15º)	+ 14º2′ to +19º40′	1.4707 to 1.4738	1.4 to 2.8	81.2 86.8*	Soluble in 1 to 2 vol. of 80% alcohol
Gildemeister & Hoffmann (1961)	0.894 to 0.910 (15º)	+15º0′ to +25º0′	1.470 to 1.476	Up to 1.5	10 to 38 41 to 78*	Soluble in 1 to 2 vol. of 80% alcohol
EOA Book of Standards, USA	0.890 to 0.906 (15º/15º)	+14º to +24º	1.4700 to 1.4750	>2.5	68 to 86	Soluble in 2 vol. of 80% alcohol
Fenaroli's Hand Book of Flavor Ingredients (1985)	0.886 to 0.902 (20º)	+13º to +24º	1.4000 to 1.4760	<1.4	–	1:1 to 1:2.2 vol. of 80% alcohol

* after acetylation.

19.7 References

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20

Nutmeg and mace

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20.1 Introduction

Nutmeg and mace are two different parts of the same fruit of the nutmeg tree, *Myristica fragrans Houtt.* (Myristicaceae). The nutmeg tree is indigenous to the Banda islands in the Moluccas. The species of the genus Myristica are distributed from India and South-East Asia to North Australia and the Pacific Islands. Sinclair (1958) listed a total of 72 species distributed in these areas. The major nutmeg growing areas are Indonesia and Grenada (West Indies). It is also grown on a smaller scale in Sri Lanka, India, China, Malaysia, Western Sumatra, Zanzibar, Mauritius and the Solomon Islands.

Nutmeg belongs to a small primitive family Myristicaceae with about 18 genera and 300 species. Myristica is the most primitive genus of the family (Sinclair, 1958). Warming (1890) and Talbot (1902) opined that Myristicaceae is closely related to Lauraceae. But there is evidence from morphological and anatomical studies that Myristicacea is more closely related to Annonaceae and Canellaceae (Wilson and Maculans, 1967). At present Myristicaceae is considered as a member of Magnoliales or its taxonomical equivalents (Cronquist, 1981; Dahlgren, 1983).

Nutmeg is a conical tree reaching a height of 4 to 10 metres. The tree is dioecious with male and female flowers occurring on different trees. Nutmeg tree is obligatory cross pollinated and an ant mimicking flower beetle (*Formicomum braminus* – Anthridae) is an effective pollinator in South India (Armstrong and Drummond, 1986). The fruits are pendulous, broadly pyriform, yellow, smooth, 7–10 cm long, fleshy splitting open into two halves when ripe, showing the ovoid 2–3 cm long dark brown shining seed with hard seed coat, surrounded by a lanciate red aril attached to the base of the seed. The seed of nutmeg is large with ruminate endosperm and is considered as the most primitive among the flowering plants (Corner, 1976).

20.2 Production and chemical structure

Nutmeg and mace are the two major primary products of *Myristica fragrans* and are commercially considered as spice. Nutmeg is the dried kernel of the seed and mace is the dried aril surrounding the seed. Both the spices have similar flavour. However, nutmeg is reported to be slightly sweeter than mace and is more preferred in food. Besides nutmeg and mace a number of other products are commercially important. Oleoresins, nutmeg butter and essential oils are also derived from *M. fragrans* and they find varied uses in the food, medicine and perfume industries.

Nutmeg is produced in the tropical areas of Indonesia and the West Indies. World production of nutmeg is about 12 000 tons per year with an annual world demand of 9 000 tons. Production of mace is about 2 000 tons. Indonesia and Grenada dominate production and export both products with a world market share of 75% and 20% respectively. Other producing countries include India, Malaysia, Papua New Guinea, Sri Lanka and a few Caribbean Islands.

The East Indian islands of Siauw, Sangihe, Ternate, Ambon, Banda and Papua produce highly aromatic nutmeg, traded as East Indian nutmeg. Grenada produces the West Indian nutmeg which is milder in flavour and lighter in colour. International trade in nutmeg is either of the East Indian or the West Indian nutmeg, with a negligible quantity of wild 'Bombay' nutmeg imported by USA. The principal import markets are the European Community, the USA, Japan and India. Singapore and the Netherlands are the major re-exporters. USA is the biggest individual market for whole nutmegs. US importers prefer the East Indian type of deep brown, aromatic nutmeg and orange red mace in their whole form. Indonesia has traditionally been the principal supplier of nutmeg and mace to the US market, accounting for an average 65% of total US imports of nutmeg per year in terms of volume.

20.2.1 Nutmeg

Fruits are harvested when they split open on ripening. The split fruits are either plucked from the tree with a hook bill or are collected soon after they drop onto the ground. Nutmeg is dried in large trays by various procedures. The unshelled nutmegs are dried in the sun until the seeds inside rattle on shaking. Normally nutmeg dries in about a week. The seed cover is removed by breaking the hard seed coat mechanically. Nutmeg is usually packed in double layered linen, jute, sisal or polythene bags. If other packing materials are used, care must be taken to avoid materials which might lead to 'sweating' and mould development. Packaging should be such that the maximum weight loss is 10%. Spices must be dried thoroughly prior to shipment. They can then be transported in conventional vessels. Powdered nutmeg is prepared by grinding at ambient temperature. Since during traditional grinding, most of the volatile oil escapes and quality deteriotes, chill conditioning and cryogenic grinding are alternative methods followed at present (McKee and Harden, 1991). The myristicin fraction of the volatile oil together with elemicin is responsible for the hallucinogenic property of the seed.

20.2.2 Mace

Mace is detached from the nut carefully soon after harvest, washed, flattened by hand or between boards and then sun dried until they become brittle. Hot air ovens can be used

Table 20.1 Composition of nutmeg and mace (%)

Composition	Nutmeg	Mace
Moisture	40.00	40.00
Volatile oil	11.00	15.30
Non-volatile ether extract	33.60	21.98
Starch	30.20	44.05
Sugars		
Glucose	0.10	0.17
Fructose	0.07	0.10
Total reducing sugars	0.17	0.27
Sucrose	0.72	0.39
Total sugars	0.89	0.65
Protein	7.16	9.91
Crude fibre	11.70	3.93
Total ash	2.57	1.56
Ash insoluble in HCl	0.20	0.15
Polyphenols		
Total tannins	2.50	–
True tannins	1.00	–

Source: Gopalakrishnan (1992).

for drying and the colour retention is much better than sun dried mace. Dried mace is graded and packed. The fixed oil content of mace ranges from 20 to 35%. The general composition of nutmeg and mace are given in Table 20.1.

20.2.3 Nutmeg oil and mace oil

The essential oil from nutmeg is steam distilled usually from substandard nutmeg and nutmeg oil ranges from 5 to 15% of the seed weight. The essential oil is highly sensitive to light and temperature and yields a colourless, pale yellow or pale green oil with a characteristic odour of nutmeg. The oil is soluble in alcohol and insoluble in water. The essential oil of East Indian nutmeg and West Indian nutmeg differ in their flavour and odour characteristics. The East Indian nutmeg oil is considered superior to the West Indian nutmeg oil, having a better aroma and a higher amount of phenyl propanoid ethers (Masada, 1976) and terpenes (Lewis, 1984). The physico-chemical properties of the two oils are reported to be different (Table 20.2). East Indian nutmeg oil is also reported to

Table 20.2 Specifications of British Standards Institutions for nutmeg oil

Specification	East Indian Oil	West Indian Oil
Colour	BS 2999/37:1971 Colourless to yellow	BS 2999/38: 1971 Colourless to pale yellow
Apparent density (mass per ml) at 20ºC	0.885 to 0.915	0.860 to 0.880
Optical rotation at 20ºC	8.0º to 25.0º	25.0º to 45.0º
Refractive index at 20ºC	1.4750 to 1.4880	1.4720 to 1.4760
Solubility in ethanol (90 per cent (v/v) at 20ºC)	3.0 volumes	4.0 volumes

Source: Purseglove *et al.* (1981).

Table 20.3 Composition of nutmeg oils of different geographical origins (%)

Source component	Grenada	St. Vincent	Malay seedlings	Papua	Indonesia	Penang	Singapore (1)	Singapore (2)
α-pinene	10.6	12.6	12.8	21.3	18.0	19.9	21.2	19.2
Camphene	0.2	0.2	0.2	0.3	0.3	0.3	0.3	0.4
β-pinene	7.8	12.1	9.3	14.3	9.7	17.7	12.7	11.0
Sabinene	50.7	49.6	44.1	30.0	27.0	36.3	17.8	15.4
Myrcene	2.5	2.8	2.9	2.4	2.2	2.5	2.6	2.3
α-phellandrene	0.4	0.6	0.6	0.5	0.5	0.4	1.0	0.7
α-terpinene	0.8	1.9	1.8	1.1	2.0	0.8	4.0	2.5
Limonene	3.1	3.3	3.1	2.7	2.7	2.8	3.6	3.4
1,8-cineole	2.5	2.3	2.1	1.9	1.8	1.5	3.2	2.7
γ-terpinene	1.9	3.1	2.8	1.9	3.3	1.3	6.8	4.1
p-cymene	3.2	0.7	0.8	0.5	0.7	0.3	1.8	2.7
Terpinolene	1.7	1.2	1.2	1.1	1.1	0.6	2.1	2.6
trans-sabinene hydrate	0.8	0.3	0.5	0.1	0.6	0.2	0.3	0.5
Copaene	0.3	*	*	0.2	0.3	*	0.2	0.2
Linalool	0.9	0.4	0.2	1.0	0.3	0.2	0.8	0.9
cis-sabinene hydrate	0.7	0.2	0.4	0.2	0.6	0.2	0.2	0.4
cis-p-menth-2-en-ol	0.4	0.1	0.1	0.3	0.5	0.1	0.3	0.3
Terpinen-4-ol	6.1	3.5	6.0	3.9	7.3	2.0	9.3	10.9
cis-piperitol	0.5	0.4	0.4	0.6	0.4	0.3	0.5	0.3
Safrole	0.2	0.1	0.8	1.5	2.1	0.6	1.9	3.2
Methyl eugenol	0.2	0.1	0.5	0.2	1.2	0.6	0.6	*
Eugenol	0.2	*	0.3	0.1	0.7	0.3	*	*
Elemicin	1.4	1.3	1.7	0.4	0.5	4.6	0.3	0.3
Myristicin	0.5	0.8	4.1	10.4	13.5	3.3	6.3	12.4

* Traces detected
Source: Lewis (1984).

have a higher concentration of myristicin (up to 13.5%), than West Indian nutmeg oil (less than 1%) (Table 20.3)

Mace oil is obtained by steam distillation of dried aril and yields 4 to 17% oil. It is a clear red or amber dark red liquid with characteristic odour and flavour. Mace oil is more expensive than nutmeg oil. Leaves also yield oil (0.34–0.65%), chemically similar to nutmeg oil, but its flavour and odour are inferior to both mace and nutmeg oil.

Extraction of essential oil can be carried out by different methods. However, mace oil extracted using liquid and dense carbon dioxide was superior in quality and flavour compared with the steam distilled oil (Naik *et al*., 1988). Essential oil has got several compounds, most of which are invaluable to industries. Because of its aroma, the essential oil is used as a natural flavouring extract in cosmetic industries. In addition to its use in cosmetic industries, nutmeg is also used in the pharmaceutical industry. The pharmacological properties of nutmeg are attributed to the compounds found in the essential oil. The first report on nutmeg constituents was by Frederick Power and Henry Salway (Power and Salway, 1907, 1908). Numerous compounds have been isolated from nutmeg and mace. The yield and quality of the oil depends on the geographical location (Table 20.3), grades and the distillation process involved. The major constituents of both nutmeg and mace oil are monoterpene hydrocarbons, together with smaller amounts of oxygenated monoterpenes and aromatic ethers (Purseglove *et al*., 1981).

Major constituents of the monoterpene hydrocarbons are pinene and sabinene and the major aromatic ether constituent is myristicin. Aromatic ethers, myristicin, safrole and elemicin determine the flavour and medicinal properties to a great extent. A recent GC analysis of the oils of nutmeg and mace showed 33 constituents in nutmeg oil and 51 in mace oil. Both the oils are qualitatively similar in composition, differing only in their quantity. Nutmeg oil consists of 76.8% monoterpenes, 12.1% oxygenated monoterpenes and 9.8% phenyl propanoid ether whereas mace oil contains 51.2% monoterpenes, 30.3% oxygenated monoterpenes and 18.8% phenyl propanoid ethers (Table 20.4) (Mallavarapu and Ramesh, 1998), and the composition varies with the geographical location (Baldry *et al*., 1976; Masada, 1976; Lawrence, 1981; Kumar *et al*., 1985; Gopalakrishnan, 1992). The Indonesian nutmeg contained 2% myristicin compared with 0.13% in *M. argentea*. No myristicin was reported in *M. muelleri*. The safrole content, a suspected carcinogen, was 0.13, 0.51 and 0.245 in *M. fragrans*, *M. argentea* and *M. muelleri*, respectively (Archer, 1988). The myristicin fraction together with the elemicin is responsible for the hallucinogenic properties of nutmeg seed. The composition of essential oil changes on prolonged storage. The structure of some of the compounds are given in Fig. 20.1.

During storage and transportation, oils should be protected from light and stored in tightly-packed containers at a temperature not exceeding 25ºC. Prolonged storage deteriorates the composition of the oil.

20.2.4 Nutmeg oleoresin

Nutmeg oleoresin is obtained by solvent extraction of spices. Oleoresins contain saturated volatile oil, fatty oil and other extractives soluble in the particular solvent employed. Nutmeg oleoresins, obtained by solvent extraction from the dried spice of nutmeg, are used in colouring and flavouring in the food industry. The spice oleoresin can be used in place of the dried spice. The commercial products exhibit a range in their essential oil and fixed oil content depending on the method of extraction and solvents employed. Nutmeg extracted with benzene yields 31 to 37% of oleoresins and with cold ethanol yields 18 to 26%. A higher fatty oil is obtained by hydrocarbon solvents while polar solvents like alcohol and acetone yield low fatty oils and resins. Commercial mace oleoresins are available with volatile oil content ranging from 10 to 55%. When extracted with petroleum ether, it yields 27 to 32% and contains 8.5–22% volatile oils, and after chilling the yield reduces to 10–13% (Naves, 1974). Oleoresins extracted with non-polar solvents are preferred in flavouring processed foods since they are more stable to heat, whereas the perfume industry prefers polar solvents since they are soluble in most perfume materials and do not deposit any fatty materials in the bottles or containers (Purseglove *et al*., 1981).

20.2.5 Nutmeg butter

The fixed oil of nutmeg is known as nutmeg butter. Nutmeg butter contains 25 to 40% fixed oil, which is obtained by expressing the crushed nuts or by extracting with solvents. Fixed oil is a semi solid, or reddish brown fat with both the aroma and taste of nutmeg. It is completely soluble in hot alcohol and sparingly soluble in cold alcohol. The fixed oil is freely soluble in ether or chloroform and is composed of trimyristin (84%), unsaponifiable constituents (9.8%), oleic acid (3.5%), resinous materials (2.3%), linolenic acid (0.6%) and formic, acetate and cerotic acids in traces. Trimyristicin is a

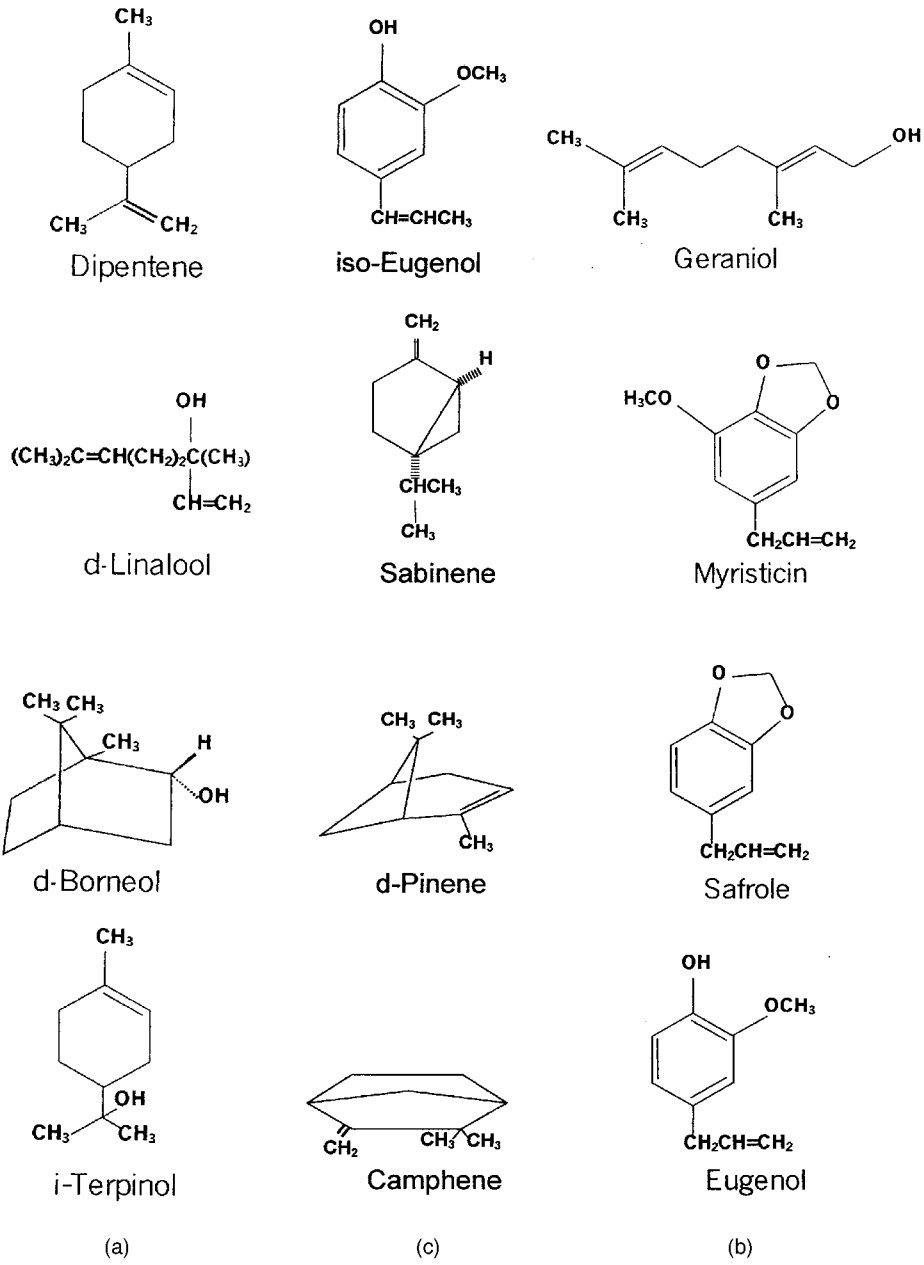

Fig. 20.1 Chemical structures.

triglyceride of myristic acid and is volatile to yellowish grey solid. Reports say that the best nutmeg butter is imported from the East Indies. The fixed oils are also used in perfumes and medicines. In medicines, it is used for external application for sprains and rheumatism.

20.3 Main uses and functional properties

20.3.1 Food

Nutmeg, mace, their oleoresins and essential oils are used in the food and beverage industries. Although whole nutmeg is available, ground nutmeg is more popular. The spice in the ground form is mainly used in the food processing industry. In South-East Asia, China and India, both the spices are used sparingly.

Nutmeg is a standard seasoning in many Dutch dishes. Nutmeg and its oleoresin are used in the preparation of meat products, soups, sauces, baked foods, confectioneries, puddings, seasoning of meat and vegetables, to flavour milk dishes and punches. The fleshy outer cover of the fruit is crystallized or pickled or made into jellies.

Mace is sold either as whole or as ground spice and is used in savory dishes. Mace is used to flavour milk-based sauces and processed meats like sausages. Soups, pickles and ketchup, pickles and chutneys are also seasoned with mace. Because of its aroma, the essential oil is used as a natural flavouring extract and is employed for flavouring food products and liquors. Nutmeg oil and mace oil are used mainly in flavouring soft drinks, canned foods and meat products.

20.3.2 Functional properties and toxicity

Both nutmeg and mace are used in the pharmaceutical industries. Powdered nutmeg is rarely administered alone but it enters into the composition of numerous medicines as aromatic adjuncts. The use of essential oils in aromatherapy is gaining importance. The main constituents of nutmeg and mace, myristicin, elemicin and isoelimicin when presented in aroma form, act as stress relievers. In Japan, many companies diffuse such aromas through air ventilation systems to improve the work environment as well as the quality of air.

It is more commonly used in Oriental than in Western medicine. Medicinally it is known for its stimulative and carminative properties. The seeds are carminative, stomachic, astringent, deodorant, narcotic, aphrodisiac and useful in flatulence, nausea, and vomiting. The antioxidant properties of nutmeg have been discussed by various authorities (Madsen and Bertelsen, 1995; Lagouri and Boskou, 1995).

Oil of nutmeg is useful in the treatment of inflammation of the bladder and urinary tract, halitosis, dyspepsia, flatulence, impotence, insomnia and skin diseases. It is also used externally as a stimulant and the ointment as a counterirritant. Essential oil has got several compounds, most of which are valuable in industry. Most of the pharmacological properties of nutmeg are attributed to the compounds found in the essential oil. Mace oil possesses almost identical physiological and organoleptic properties as nutmeg oil. Nutmeg butter is a mild external stimulant used in the form of ointments, hair lotions and plaster, and used against rheumatism, paralysis and sprains.

Both nutmeg and mace contain the active ingredient myristicin which possesses narcotic properties. Nutmeg butter contains elemicin and myristicin which are also narcotic and cause psychotropic effects. Ingestion in large quantities produces narcosis, delirium, drowsiness, epileptic convulsions and even death. It also causes temporary constipation and difficulty in urination and increased fat deposition in liver. Powdered nutmeg is used occasionally as a hallucinogenic drug, but such use is dangerous as excessive dose of mace has a narcotic effect and symptoms of delirium and epileptic convulsions appear after 1–6 hours of consumption.

20.3.3 Perfume and other uses

Nutmeg oil is used in cosmetics, men's perfume and toiletries due to its aromatic properties. Mace oil possesses almost identical physico-chemical and organoleptic properties as nutmeg oil. Mace oil is also used to a limited extent in perfumes and soaps.

The myristicin component which imparts the hallucinogenic properties is also reported to be an effective insecticide. The lignin type of constituents in the nut are anticarcinogenic. Camphene present in the oil is used in the manufacture of camphor and related compounds and has strong antibacterial, antifungal and insecticidal properties. Pinene of the essential oil of nutmeg is used to make camphor, solvents, plasticizers, perfume bases and synthetic pine oil. Dipentene is used in the manufacture of resins and is used as wetting and dispersing agent. Myristic acid is used in the preparation of soaps, liquid detergents, shampoos, shaving creams, perfumes, plastics, in compounding rubber, paints and greases, in the synthesis of esters for flavours and perfumes and as a component of food grade additives. Resorcinols (malabaricone and malabaricone C) isolated from the mace exhibited strong antibacterial and antifungal activities against *Staphylococcus aureus* and *Candid* (Orabi *et al.*, 1991). Larvicidal properties are also reported in mace, the larvicidal principle in mace was identified as diarylnonanoid, malabaricone C against second stage larvae of *Toxocara canis* (Nakamura *et al*., 1988).

20.4 Quality issues

Nutmeg and mace are classified by origin (East Indian nutmeg and West Indian nutmeg) and grade. Good quality has to be maintained for trade of nutmeg and mace. Whole nutmegs are grouped under three broad quality classifications:

- *Sound*: Nutmegs which are used mainly for grinding and to a lesser extent for oleoresin extraction.
- *Substandard*: Nutmegs which are used for grinding, oleoresin extraction and essential oil distillation.
- *Distilling*: Poor quality nutmegs used for essential oil distillation.

In Indonesia, high quality of sound whole nutmeg are traded in grades which refer to their size in numbers of nutmeg per pound: 80s, 110s and 130s or 'ABCD' which is an assortment of various sizes. Substandard nutmegs are traded as 'sound, shrivelled', which in general have a higher volatile content than mature sound nutmegs and are used for grinding, oleoresin extraction and oil distillation, and 'BWP' (broken, wormy and punky) which are used mainly for grinding as volatile oil generally does not exceed 8%. Distilling grades of nutmeg are of poor quality: 'BIA' or 'ETEZ' with a volatile oil content of 8% to 10% and BSL or 'AZWI' which has less shell material and a volatile oil content of 12–13%.

In Grenada, sound nutmegs are sold as sound unassorted which corresponds to the Indonesian grade 'ABCD'. Substandard nutmegs are classified as floats and as defective, the latter is similar to the Indonesian BWP grade but considered of high quality. Distilling grades of nutmegs are primarily exported to the USA and consist of floats.

Mace is classified as whole pale mace, No. 1 broken mace, selected, unassorted or siftings (Indonesia) and as whole, broken blades or siftings (Grenada). The International Standards applicable for trade in spices of nutmeg and mace are ISO 6577:1990.

Though national standards are available for maintaining the quality (see Tables 20.2, 20.5, 20.6 and 20.7), the European traders prefer the ASTA cleanliness specifications

Table 20.5 American Spice Trade Association (ASTA) cleanliness specifications

Product	Insect (by count)	Excreta mammalian (mg/lb)	Excreta other (% wt)	Mould (% wt)	Insect infested (% wt)	Foreign matter (% wt)
Nutmeg (broken)	4	5	1.0	*	*	0.5
Nutmeg (whole)	4	0	0.0	*	*	0.0
Mace	4	3	1.0	2.0	1.0	0.5

* Not more than 5% by weight insect defiled and mould infected.
Source: Sivadasan and Kurup (1999).

Table 20.6 Defect Action Levels prescribed by US Food and Drug Administration for spices

Mace	
Insect filth and/or mould	Average of 3% or more pieces by weight are insect infested and/or mouldy
Mammalian excreta	Average of 3 mg or more of mammalian excreta per pound
Nutmeg (whole)	
Insect filth and/or mould	Average of 10% or more pieces by count are insect infested and/or mouldy

Source: Sivadasan and Kurup (1999).

(Table 20.5) as they are more strict than the National standards. The Quarantine System and Plant Protection Law and the Food Sanitation Act set the quality standard in Japan. Aflatoxin (The Netherlands, Japan) and salmonella (United Kingdom) are the common complaints on the imports of nutmeg. The presence of insects is a major complaint for US importers.

Adulteration is common in the nutmeg trade. The essential oil has often been extracted before they are marketed and such nuts can be detected by their light weight and are more subjected to insect attack. *M. fragrans* is adulterated with *M. argentea*, *M. malabarica* and *M. otaba* which can be identified by their poor quality. The mace from *M. argentea* is imported as Papuan nutmeg from Papua New Guinea, *M. malabarica* is traded as Bombay nutmeg from India and from *M. otaba* as *Otaba* nutmeg. Trade of wild nutmeg exists and they are marketed as long, female, Macassar, Papua, Guinea, or Norse nutmeg. All these have been traced to *M. argentea* of New Guinea from where they enter into the market as Macassar nutmegs. *M. malabarica*, *M. otaba* and *M. argentea* are devoid of any aroma of *M. fragrans*.

Table 20.7 Dutch regulations for cleanliness specifications

Product	Ash content (max. %)	Sand content (max. %)	Volatile oil (min. %)	Others
Nutmeg	3.5	0.5	4.0	NVEE * 5.0
Mace	3.5	0.5	4.0	NVEE * 4.0

* NVEE – Non-volatile ether extract
Source: Sivadasan and Kurup (1999).

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21

Onion

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21.1 Introduction

Onion is a famous spice commodity grown all over the world and consumed in various forms. It has been in cultivation for more than 4000 years. The maximum diversity of *Allium* species is found in a belt from the Mediterranean basin to Iran and Afghanistan, i.e. Iran, north Iraq, Afghanistan, Soviet middle-Asia and west Pakistan,[1] indicating the primary centre of origin. The earliest record comes from Egypt where onions appear as carvings on pyramid walls and in tombs from the third and fourth dynasties (2700 BC).[2] It is thought that Romans took the onion north of the Alps. The onion was among the first cultivated plants taken to the Americas from Europe. Europeans took the species to East Asia during the last century.

The distinctive flavour of alliums have established plants as an essential part of the cuisine of the world. It is used as immature, mature bulbs as vegetable and spice as well as food for poultry and non-milking cattle. In India and China, onion is the basis of many dishes. Nearly every Indian recipe starts with the same procedure. Fry chopped or sliced onion slowly, add spices (frequently fresh garlic and ginger and dried spices like cumin, turmeric, chillies) and fry until the onion turns golden. The mixture (wet masala) may afterwards be puréed, simmered with tomatoes or yogurt or just added to boiled or fresh vegetables, meat, chicken and fish to form curry. The onion rings can be fried and used as fast food. Onion *pakodas* made out of sliced onion and chickpea flour is an important snack item in Indian hotels. Onion can be eaten raw or cooked; mild flavoured or coloured bulbs are often chosen for salad.

Alliums are also used widely in food processing. However, handling of bulk of onion and storage of bulbs for 5–6 months is cumbersome. Losses of fresh onion in storage have been reported to be about 25 to 30%.[3] Value addition of raw onion in the form of processed products is the most practical solution. Whilst onion is traded in its raw form, the international market is increasingly focused on dehydrated products such as flakes, rings, granules, powder, etc., and processed onion as frozen or canned, or onions in vinegar and onions in brine.

Allium cepa is cultivated mainly as a biennial, but some types are treated as perennials. It is propagated by seeds, bulbs or sets (small bulbs). Very wide variation in shape, size

and colour is observed in this species. Intensive selection during domestication and natural hybridization might have created variability. There is a lot of controversy regarding the taxonomic position of *Allium* and related genera. In early classification onion was placed in the *Liliaceae*. Some British and American botanists included onion in *Amaryllidaceae*. In a more recent taxonomic treatment of monocotyledons, *Allium* and its close relatives are recognized as the distinct family *Alliaceae*, close to *Amaryllidaceae*. Robinowitch and Brewster[1] suggested the following hierarchy:

1. Class: *Monocotyledones*
2. Super order: *Liliiflorae*
3. Order: *Asparagales*
4. Family: *Alliaceae*
5. Tribe: *Allieae*
6. Genus: *Allium*

Jones and Mann[4] gave simple classification of genus *Allium cepa* for the use of horticulturists as under:

- **a**. **Common Onion Group** (*Allium cepa* L. var. *Cepa; Allium cepa* L. ssp. *Cepa*, and ssp. *Australe Trofim*): Bulbs are large, normally single. Plants produce from seeds or from seed grown sets. The majority of cultivars grown for dry bulbs belong to this group. This is the most important group of trade grown all over the world. It includes hundreds of open pollinated varieties, land races and commercial F_1 hybrids. Maximum diversity exists in southwest Asia comprising countries like India, Pakistan, the former Soviet Republics and also Mediterranean countries.
- **b**. **Aggregatum Group or Shallots** (*Allium ascalonicum auct*. Non strand; *Allium cepa* L. ssp *orientale kazak*): Bulbs are smaller than common onions and several to many form an aggregated cluster. Reproduction is almost exclusively vegetative via daughter bulbs. Occasionally scapes are developed and in some types, seed production is possible. This group is of minor importance. Locally adapted cultivars are grown mainly in home gardens. Cultivars are more suited to humid tropical regions of Asia, West Africa and the Caribbean area.
- **c**. **Ever-Ready Onion** (*Allium cepa* L. var. *perutile stearn*): Bulbs are narrow with shorter flower stalks and smaller umbel. Bulbs or leaves can be gathered at all times of the year. It is used mainly as salad onion. This group is again sub-divided into potato or multiplier onion and shallots.
  - (i) **Potato or Multiplier Onion**: The bulbs divide into between 3 and 20 bulb sets that are wider than they are long. They are covered by outer dry skins.
  - (ii) **Shallot**: Shallots form cultures of narrow, separate bulbs. The leaves and flowers are usually smaller than common onion. Shallots are suitable for high latitude and short season regions.

21.2 Chemical structure and influences on flavour

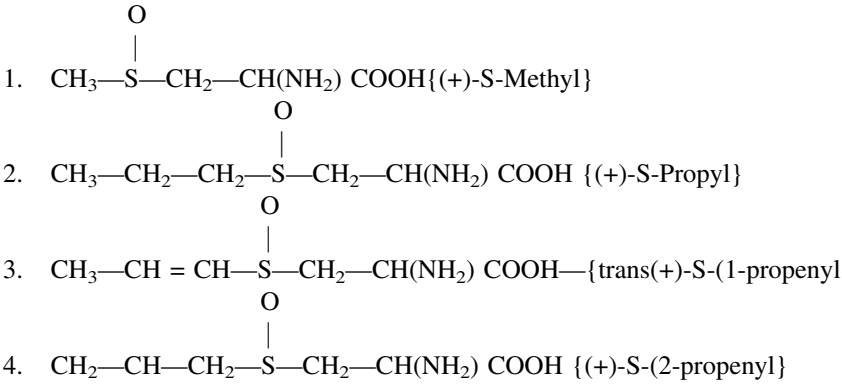
The importance of onion lies in the flavour that it imparts to various other dishes. A common onion contains the following nutrient components:[5]

Moisture	88.6–92.8%
Protein	0.9–1.6%
Fat	Trace–0.2%

Carbohydrates	5.2–9.0%
Ash	0.6%
Energy	23–38 cal $100g^{-1}$
Elements	mg $100g^{-1}$ fresh weight
Ca	190–540
P	200–430
K	80–110
Na	31–50
Mg	81–150
Al	0.5–1
Ba	0.1–1
Fe	1.8–2.6
Sr	0.8–7
B	0.6–1
Cu	0.05–0.64
Zn	1.5–2.8
Mn	0.5–1.0
S	50–51
Vitamins	$100g^{-1}$
Vitamin D	0.3 mg
Riboflavin	0.05 mg
Nicotinic acid	0.2 m
Vitamin C	10.0 mg
Folic acid	16.0 μg
Biotin	0.9 μg
Pantothenic acid	0.14 mg

Among various free amino acids which vary greatly, glutanic acid and orginine are abundant in onion. The concentration of these amino acids is higher at the centre of the bulb and decreases towards the outer scales.

Onion is characterized by its distinctive flavour and pungency which is due to sulphur containing compounds available in the scales of bulbs. The sulphur is in the form of various non-protein amino acids which include the precursors of volatile flavour compounds. These precursors are odourless, non-volatile amino acids of general name S-alk(en)yl cysteine sulphoxides.[6] The precursors occur naturally in four types:



Intact onion cells have no odour, but when cells are disrupted the enzyme alliinase is released. This enzyme hydrolyses the S-alk(en)yl cysteine sulphoxides to produce pyruvate, ammonia and many volatile sulphur compounds associated with flavour and odour.[7] The enzyme is confined to cell vacuole, whereas the flavour precursors are confined to cytoplasm. The enzyme has access to precursors only when cells are disrupted. Boiled onion does not produce flavour as the enzyme is destroyed before having access to the flavour precursors. The tear-producing character of onion on cutting is known as the lacrimatory factor. Lacrimator is formed enzymatically during the hydrolysis of S-propenyl cysteine sulphoxide.[8] Thus alliums with S-propenyl cysteine sulphoxide have a tear-producing effect and alliums with S-allyl cysteine sulphoxide resemble the taste of garlic.

Besides the bulb, the flavour precursors are also available in leaf blades, base plate, and roots of onion. However, they are absent in seeds.[9] The taste of onion differs from variety to variety and within varieties grown under different conditions and different growth stages. Flavour precursors are synthesized in leaf blades and transported to the scales of bulb where they are stored.[10] Younger blades are more productive than older ones. Precursor content increases during bulbing and then gradually decreases towards maturity. During storage of bulbs, the flavouring compounds increase; although the bulb is in a resting stage, it is still metabolically active. The increase in sulphur content is maximum until the sprouting of bulbs. The level of sulphur suddenly drops after sprouting. The reduction of flavour at the end of storage period may be due to metabolism and translocation of the flavour precursors themselves for nutrients for developing roots.[11] Kopsell *et al.*[12] observed increase in trans-(+)-S-(1-propenyl)-1-cysteine sulphoxide in seven cultivars under study. There was decrease in S-methyl-L-cysteine sulphoxide.

As well as genotype and stage of growth, environmental factors exercise great effect on flavour strength. The bulbing response in onion is a function of temperature and photoperiod. Plants grown at higher temperature under optimum photoperiod bulb more rapidly than those grown at lower temperatures. A threefold increase in volatile sulphur at higher temperature was observed by Platenius.[13] The varieties grown in India and Pakistan produce bulbs with higher pungency as they mature during temperature range between 25–35ºC. Similarly high amount of watering produce bulbs with less flavour.[13] Soil fertility status and high amount of sulphur containing fertilizers alter the flavour strength. More pungent bulbs were produced by Platenius on peat than sandy soil.[13] Addition of sulphur in major nutrients was found to increase pungency in onion bulbs.[14]

21.3 Production

A global review of area and production of onion shows that it is grown in 126 countries over an area of 2.3 million hectares producing 40.0 million tons of dry onion. Sixty-two per cent of the world's production is from Asiatic countries. Among them, China (19.3%) and India (17.8%) are the giants by area as well as by total production. The world's onion productivity is 17.16 tons/hectare.[15] About 90% of onion is consumed within the countries of production. Total import of dry onion in the world is worth $1121.8 million, while export is $910.5 million.[16]

Onion cultivation and processing is at its most advanced in countries such as the United States. Systematic breeding programmes for the development of high TSS white onion varieties launched by various research organizations and seed companies in the United States has been the backbone of the processing industry. Development of suitable

varieties in short-day onion grown in Asiatic countries holds good promise with the available input. India exports dehydrated onion (4124 tons) and processed onion (9095 tons) worth Rs.178.11 million and 191.85 million, respectively.[17]

21.3.1 Dehydrated onion

Onion is dehydrated in the form of flakes, rings, kibbles and powder. A large part of dehydrated onion production is used as seasoning in production of catsup, chilli sauce and meat casseroles as well as cold cuts, sauces, soup, mayonnaise, salad dressing, sweet pickles, dog food, potato chips, crackers and other snack items. Food service outlets also use dehydrated onion because of its convenience in storage, preparation and use. Processing units require white onion varieties with important attributes:

- white onion with globose shape, free from greening
- high total soluble solids (>20%)
- high degree of pungency
- high insoluble solids
- low reducing to non-reducing sugars ratio to avoid caramelization
- high yields
- good storage quality

Important cultivars for dehydration include white Creole, Southport White, Dehydrator No. 8, Dehydrator No. 14, VH-12, etc. Indian varieties are of short-day type and do not possess total soluble solids more than 15%. However, due to high pungency they make good quality dehydrated flakes and granules. The coloured varieties like dark red, red and yellow are also used for dehydration purposes but the quality of dehydrated produce is inferior to white varieties.

Traditionally onion dehydration is performed by sun drying in India, on a domestic scale. Various types of solar driers have also been designed for dehydration purposes.[18] However, controlled drying under optimum temperature and time gives good quality product. Cabinet drying at 55–60ºC for 10–15 hours gives a better quality dehydrated product than sun drying and drying in solar huts.[19, 20] Commercial dehydration is achieved by forced hot air with the total process divided into three stages: drying at 75, 65 and 55–60ºC, the conditions of dehydration becoming milder as the moisture content falls.[5] Van Arsdel *et al.* [21] have given a schematic representation of the process for onion dehydration as shown in Fig. 21.1.

The process is completed by placing the dehydrated onion pieces in bins where the final moisture content (~4%) is achieved via the circulation of warm air currents. The approximate composition ($100\,g^{-1}$) of dehydrated onion should be as shown in Table 21.1.[22]

21.3.2 Onion oils and other onion products

There are a number of other onion products.

- *Onion oils*: Concentrated oils extracted from onion can be used to impart the flavour of onion to processed food without the difficulties of handling a large bulk of fresh bulbs.[6] Onion oil is obtained by the distillation of minced onions which have been allowed to stand for a number of hours before distillation. The oil is of dark amber

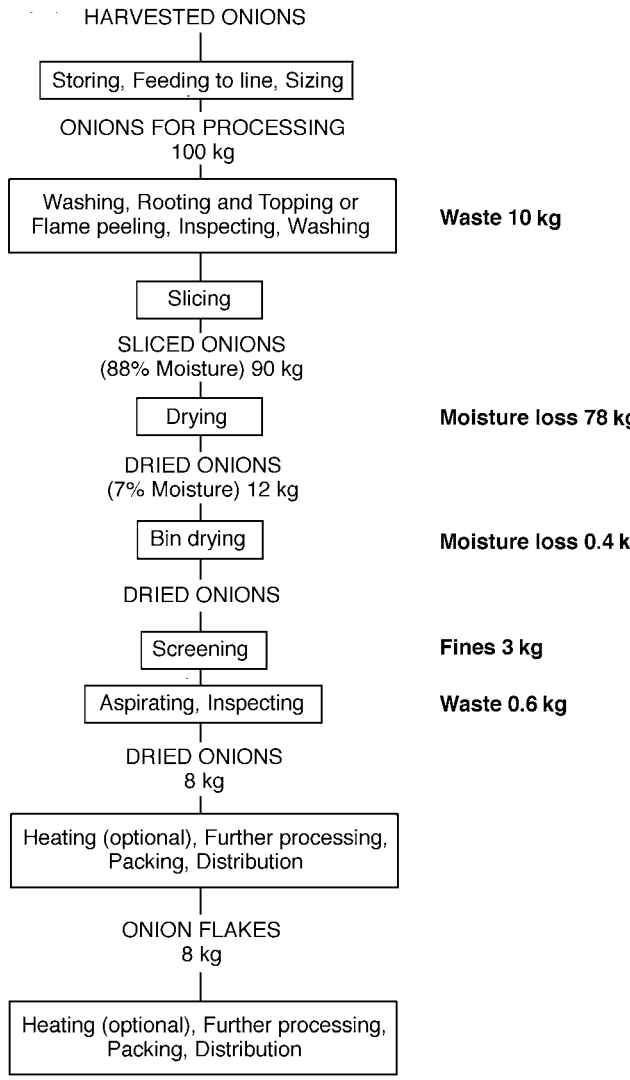


Fig. 21.1 Onion dehydration process.

coloured liquid. The yield of oil varies from 0.002 to 0.03%. One gram of oil is equivalent to 4.4 kg fresh onions or 500 g onion powder.[22] Use of onion oil is very safe from a microbiological contamination point of view, but there is the problem of flavour being lost. Onion oil is also used in non-alcoholic beverages, ice creams, confectionery, baked goods, condiments, meats and pickles.[5]

- *Onion juice*: Onion juice with low flavour component is another processed product. Massarated pulp of onion is flash heated (140–160ºC) and then cooled at 40ºC. The product is evaporated to 72–75% solids to facilitate preservation. During processing aromatic components may be removed so that the product has a low flavour profile.[22]
- *Onion salt*: Onion salt is prepared by mixing 19–20% onion powder with 78% free flowing pulverized refined table salt and 1–2% anti-caking agent which prevents water absorption, and caking, etc.[23]

Table 21.1 Composition of dehydrated onion[22]

Water	5.0 g
Energy	347 Kcal
Protein	10.1 g
Fat	1.1 g
Carbohydrates	80.7 g
Fibre	5.7 g
Ash	3.2 g
Ca	363 mg
Fe	3 mg
Mg	122 mg
P	340 mg
K	943 mg
Na	54 mg
Zn	2 mg
Vitamins (ascorbic acid)	15 mg

- *Onion pickles*: Pickled onions are eaten in large quantities in many European countries. Onion pickles are prepared out of two types, namely (i) brown or dark red onion 28–45 mm diameter and white or silver skin (pearl or cocktail) onions between 10 and 28 mm in diameter.[5] These onions are produced by planting with high plant density. The onions are first peeled and allowed to ferment in 10% brine solution for 24–96 hours. During fermentation sugars from the bulbs are converted to lactic acid and a small amount of acetic acid and alcohol. The fermentation is controlled by adding small quantities of lactic acid. The pickled bulbs are bottled in vinegar, possibly darkened with caramel and pasteurized at 80ºC.[6]
- *Vinegar from onion*: A new type of vinegar can be produced from onions that have been rejected for other conventional purposes because of low quality.[24] Horiuchi *et al*.[24] tested several types of onion as raw material for vinegar production. Vinegar was produced successfully from juice of red onion cv. Kurenai by batch culture using yeast and *Acetobacter aceti*. The vinegar produced from onion had a higher potassium content, while sodium was lower than in conventional vinegars. The total amino acid and organic acid contents of onion vinegar was much higher than in other kinds of vinegars. The commercial feasibility of this new type of product needs to be assessed. In a country like India a colossal quantity of red onions go to waste during the lean season and these can best be utilized for value addition.

21.4 Functional properties

Besides use as a condiment and spice for flavouring and enriching various cuisines, onion has been known for its high medicinal properties for thousands of years. Chinese, Indians and Egyptians have known about its various medicinal properties since antiquity and these have been well documented. *Charak Samhita*, an ancient Indian medical treatise describes many curative uses of onion. Augusti[25] listed various traditional uses of onion, including:

- It acts as stimulant, diuretic and expectorant and mixed with vinegar, it is useful in the case of sore throat.
- Essential oil from onion contains a heart stimulant, increases pulse volume and frequency of systolic pressure and coronary flow.

- Onion consumption lowers blood sugar, lipids and cholesterol.
- Fresh onion juice has antibacterial properties due to allicin, disulphide and cysteine compounds and their interactions.
- Antiplatelet aggregation effect in human and animal blood has been reported due to regular consumption of onion.[26, 27]

The antioxidant activity of onion (*Allium cepa*) and onion scales has been studied in lipid oxidation models[28–33] and in radical scavenging assays.[34, 35] Both yellow and red onion were poor antioxidants towards oxidation on methyl linoleate[33] contradictory to high antioxidant activity towards oxidation of LDL.[35] Onion had also a poor antioxidant score in the ORAC activity test while garlic (*Allium sativum* L) expressed a score four times higher.[34] Yin and Cheng[36] reported that the presence of garlic bulb, garlic greens, Chinese leek, scallion, onion bulb, and shallot bulb significantly delayed lipid oxidation of phosphatidylcholine liposomes. While allicin **4** is responsible for the antioxidant activity of garlic bulb,[37] compounds other than allicin are involved in determining the antioxidant effect of other *Allium* members. According to Velioglu *et al*.[38] anthocyanin-rich vegatables including red onion scales generally showed very strong activities towards oxidation of β-carotene linoleic acid model systems. Similarly, green onion tops were reported twice as active as green onions with quercetin **5** included in the antioxidant substances.[28, 29]

21.5 Quality issues

21.5.1 Dry onions

For export from India the following specifications have been defined by the Agricultural Processed Products Export Development Authority (APEDA).[39]

A. General big onions:

1. *4–6 cm bulb diameter, light red to dark red colour, globular, pungent* – onions are suitable for Asian markets and Arab countries.
2. *3–4 cm bulb diameter, globular, pungent and light red colour* – onions are suitable for Bangladesh market.
3. *7–8 cm bulb diameter, globular and oval round shape, yellow or brown colour* – onions are suitable for European and Japanese markets.

B. Small onions:

2–3 cm bulb diameter, dark red to violet red, globular shape – onions are suitable for Malaysia and Singapore markets.

C. Multiplier onions:

2.5–3.5 cm bulb diameter, dark red colour, bigger size bulblets – onions are suitable for Malaysia, Singapore, and Sri Lanka markets.

As per international quality standards[40] dry onions should be intact, sound, clean, sufficiently dry for intended use, free from abnormal external moisture, free from off odours and the stem must be twisted or clean cut. Shape and colour should be typical to the variety. The size should be uniform with minimum variation in the group. The size of group can be of 10–20 mm, 15–25 mm, 20–40 mm, 40–70 mm and 70 mm plus. They should be free from abnormal swelling, doubles, sprouting and saprophytic fungus. The bulbs should be packed in sacks of jute or nylon nets with appropriate capacity varying from 25–40 kg. Consumer prepacks of 1–2 kg capacity, such as nets, plastic film bags or stretch-wrapped trays can be used.

Table 21.2 American Dehydrated Onion and Garlic Association quality standards and grade specifications

Products	Colour (optical index)	Bulk index (ml/100 g)
Sliced	90	400
Large chopped	90	300
Minced	150	180
Granulated	150	140
Agglomerated – coarse	150	140
Agglomerated – fine	150	140
Powdered products	150	140

21.5.2 Dehydrated products

The American Dehydrated Onion and Garlic Association have standardized quality and grade specifications for dehydrated onion products.[41] Based on particle size the products are classified as shown in Table 21.2.

In all products moisture should be 5.0%. The products should be free from black or dark brown pieces, seed stems, sediment or sediment attached to onion, extraneous vegetable matter (such as tops, rootlets, and other harmless vegetable matter), outer roots, metallic particles, hair, etc. The material should be packed in moisture barrier material like multi-walled polythene bags, fibre drums and stored under cool and dry conditions. Exposure to high temperature and light reduces the colour quality of dehydrated products.

Freshly harvested as well as stored bulbs are used for dehydration. During harvesting, handling and storage, the bulbs carry a heavy load of harmful bacteria, fungi yeast and mould. There is every possibility of passing these microbes to the final product. The count of various microbes should be at tolerable levels as follows:

Aerobic plate count	< 500.000/g
Yeast and mould	< 5000/g
Coliforms	< 200/g
Salmonella	Absent/25g
E. Coli	Absent/g

21.5.3 Other onion products

Onion is processed in the form of pickled onion, as onion in brine and onion in acetic acid. For processing, bright white onions with globose shape, fully cured, free from rots, mould, fungus, external damage, sprouting and greening are used. Bulbs of 16–25, 25–45 and 45–70 mm diameter grade are used for processing. Smaller grade fetches better

Table 21.3 Chemical composition of onions in brine and acetic acid[42]

Composition	Onions in brine	Onions in acetic acid
Salinity as NaCl	16% ± 0.5%	5% ± 0.5%
Acidity as acetic acid	0.3% ± 0.5%	4% ± 0.2%
$CaCl_2$	0.5%	0.5%
SO_2	250 ppm max	250 ppm max
pH	below 3.5	below 3.5

prices. The chemical composition of onions in brine and acetic acid should be as shown in Table 21.3.[42] The processed onions are packed in food grade HMHDPE barrels of 220–240 litre capacity.

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22

Poppy

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22.1 Introduction

Poppy is the common name for several species of the genus *Papaver* of the family Papaveraceae. It includes many species which are grown as garden flowers (garden poppies) and the species *P. somniferum* and its different varieties grown for the production of the important narcotic medicine opium (the dried latex exudate from the fully grown green capsule) and its edible seeds and seed oil. Opium is one of the oldest known painkillers and is the source of several alkaloids used for analgesic, antitussive and antispasmodic purposes in modern medicine. *P. somniferum* is named as the opium poppy. The opium poppy was cultivated by the ancient civilizations of Greece, Egypt, Italy, Persia and Mesopotamia. Poppy is now cultivated mainly for the production of opium and for the edible seed and seed oil. Poppy seeds are highly nutritive having no narcotic effect and used in breads, curries, sweets and confectioneries, and seed oil for culinary purposes.

Opium poppy is widely distributed in the temperate and subtropical regions of the old world extending from 60ºN in North-West Soviet Union to the southern limit reaching almost the tropics. The centre of origin of *Papaver somniferum* (L.) is believed to be somewhere in the western Mediterranian region of Europe from where it spread through the Balkan Peninsula to Asia Minor as early as the tertiary period (Bazilevskays, 1976; Morton, 1977).

The plant poppy belongs to the genus *Papaver* of the dicot family Papaveraceae. There are about 100 species of *Papaver* distributed all over the world. Feede (1909) divided the genus papaver into nine sections, of which two sections 'Mecones' and 'Mycrantha' (Oxytona) are the only economically important groups. Valuable alkaloid yielding and edible seed producing species like *P. somniferum, P. setigerum* D.C. belong to the section 'Mecones', but *P. somniferum* is the only species which is commercially cultivated. *P. somniferum* is not found in the wild state. But other members of this genus under the section Mecones, *P. setigerum, P. glaucum, P. glacile* and *P. dicaisnei* are found wild in the Mediterranean region. The species under the section Oxytona are *P. bracteatum, P. orientale, P. pseudo-orientale* and they also contain some opium alkaloids. *P.*

somniferum and *P. setigerum* shows close similarity and are now believed to have originated from a common ancestral stock (Vesselovskaya, 1976; Husain and Sharma, 1983; Singh *et al*., 1995a). The species which contains alkaloids are morphine, codeine, thebane, narcotine and papaverine.

P. somniferum is an erect, annual herb, 30–150 cm long with 0.5 to 1.5 cm thick stem. The root is either shy branched or much branched, tapering and yellow. The stem is glabrous with thick waxy coating. The leaves are numerous, alternate, sessile, spreading horizontally; the lower ones are about 15 cm long oval oblong deeply pinnatisect with acute segments. The upper ones reaching as much as 25 cm in length, gradually wider and with more cordate base, the uppermost ones in very broadly ovate, amplexicaul prominent veins, midrib very wide, nearly white. Puri (1983) noticed that in the race 'Safaid patta', the leaves are variegated with white streaks or blotches. In 'Kutila' or 'Kutapatta', the foliage is deeply cut into more or less narrow segments up to midrib and primary veins. A wide variation of leaf serration in Indian poppy was noticed by Nigam *et al.* (1989).

Flowers are few, solitary on a 10–15 cm long penducle. Flower buds are ovate-ovoid dropping, hermaphrodite, regular with two caducous sepals, smooth, green, petals four, very large, polypetalous, generally white. Stamens are numerous, hypogynous, arranged in several whorls; anthers are linear attached with filament, cream coloured becoming pale brown and twisted after dehiscence. Ovary large depressed, globular, smooth pale green, one-celled with large spongy parietal placentae. Stigma is sessile, capitate with 8–20 short obtuse oblong rays. The fruit is a capsule varying in colour, shape and stigmatic rays. The immature capsule is covered with a waxy coating which imparts greyish-blue line to the capsule. The mature capsule is pale-brownish and sometimes may be variegated. The mature capsule may be globose or roundish, spherical, oblong to ovate oblong, depressed in some cases. The capsule has a rounded base but ends abruptly at the apex, opening by pore beneath the stigmatic rays. The stigmatic rays vary from 7 to 18. Seeds are numerous, very small, white grey, violet or black in colour, testa with a raised reticulated network, its embryo is slightly curved in the axis of the oily endosperm.

Poppy is generally considered as a self-pollinated plant, but there occurs a certain degree of outcrossing in poppy as has been reported by some workers (Singh *et al.*, 1999). Nyman and Hall (1976) have reported as much as 97% outcrossing. Since the insects play a major role in outcrossing, more outcrossing is expected in this species. Khanna and Shukla (1983) and Bhandari (1990) observed highly variable degrees of outcrossing in poppy and reported as high as 79% outcrossing. However, planned breeding of opium poppy is very recent. Different selection methods for opium yield and quality and oil seed yield were the objectives of the breeding work. Extensive breeding work on poppy has been carried out by many European and Indian breeders (Hlavackova, 1959, 1978; Sip *et al.,* 1977; Khanna, 1978, 1981; Khanna and Gupta, 1981; Saini and Kaicker, 1982; Sharma *et al.,* 1988; Bohm, 1965; Johnson and Loof, 1973; Goldblatt, 1974; Khanna and Shukla, 1989a, b; Singh *et al*., 1999).

Singh *et al.* (1995b) reported heterosis in poppy for many economic characters. Exploiting this aspect, a number of high yielding cultivars of poppy have thus been made by selection and breeding. Development of an opiumless variety producing high seed yield and food quality oil is considered to be very important considering the high nutritional value of the poppy seed and seed oil.

22.2 Cultivation

Poppy is cultivated for the legal pharmaceutical use of opium latex in India, USSR, Egypt, Yugoslavia, Czechoslovakia, Poland, Germany, the Netherlands, China, Japan, Argentina, Spain, Bulgaria, Hungary and Portugal (Vesselovskaya 1976, Ramanathan and Ramachandran, 1977). Many European countries, however, grow poppy for its seed and seed oil. Poppy is also grown illegally for the narcotic trade and is categorized mainly in two groups:

- Golden Triangle (Burma, Thailand and Laos region)
- Golden Crescent (Afghanistan, Pakistan and Iran region)

There exist no records about the extent of illegal poppy cultivation and production.

Poppy can be cultivated in well-drained soil in open sunny locations in subtropical regions, being irrigated during dry spells. Direct sowing is better as transplanted ones do not grow well. It is a six-months crop and sowing is done mostly in autumn. In India sowing is carried out at the beginning of November and seed is harvested in April the following year. Poppy is primarily cultivated in India for opium as a rich source of morphine for medical use and for seeds and seed oil.

There are a number of varieties of *P. somniferum* L. under cultivation in India. The races with white flowers are commonly grown in Uttar Pradesh. The races with red or purple flowers were common in Madhya Pradesh and Rajasthan, but now these too are replaced by white flower types. No comprehensive taxonomic treatment on the cultivars of Indian opium poppy is available. Asthana (1954) described the different cultivars grown in India and broadly classified the races of opium poppy into 'Sabzadhari' (green, i.e., non-waxy capsules) and 'Safaidhari' (white, i.e. waxy capsules) types. During the last two to three decades, there has been a great erosion of poppy germplasm in India and many of the races described earlier by Asthana are no longer available today. To pinpoint the different races under cultivation in recent years, a detailed and classified investigation has been carried out by Khanna and Gupta (1981). They evaluated a large collection of germplasm from the various states which they categorized into basic cultivars. Not more than 20–25 basic cultivars could be recognized. Singh *et al.* (1997) has prepared a key for these cultivars on the basis of most salient features and some problems with regard to existing local names.

India is one of the largest producers of opium alkaloids in the world. As well as meeting the domestic demand, India exports opium to other countries. Its production and distribution is controlled by the Narcotic Controller of Govt. of India. At present poppy is cultivated mainly in Uttar Pradesh, Rajasthan and Madhya Pradesh. The area under poppy cultivation is controlled by the Narcotics Department, Government of India who give annual renewable licences to the farmers. The area under opium poppy cultivation is divided into 12 (opium) divisions covering the districts of Faizabad, Barabanki, Barelly and Shajahanpur in Uttar Pradesh, Neemuch I and II, Mandsaur I and II and Ratlam in Madhya Pradesh, and Kotah, Chittorgarh and Jhalawar in Rajasthan.

22.3 Chemical structure and uses

Cultivated poppy (*P. somniferum)* has great economic value because of the opium latex and also for the edible seed and seed oil. The capsule is the major organ for the opium latex, but the alkaloids are also present in other parts of the plants like stem, leaves, roots,

etc. The seeds do not contain any alkaloid, but are rich in edible oil of high quality. The straws of poppy also contain some alkaloids and are variously used in medicine.

22.3.1 Opium

Opium is brownish in colour when fresh and turns to brownish black when dried. It has a fruity odour. The total alkaloid content varies from 5–10%. It has a very complex chemical composition containing sugars, proteins, fats, water, meconic acid, plant wax, latex, gum, ammonia, sulphuric and lactic acids and numerous alkaloids (about 40 have been identified so far), most important among them including morphine (10–15%), codeine (1–3%), noscapine (4–5%), papaverine (1–3%) and thebaine (1–3%). The range of major alkaloids contained in the Indian species are morphine (7–17%); codeine (2.1-4.4%); thebaine (1.0–3.0%); noscapine (3.0–10%) and papaverine (0.5–3%). Papaver straw (dry capsule with 7.5 cm stem) contains a small quantity of alkaloid. All these compounds except thebaine are used medicinally as analgesics. The opioid analgesics are of inestimable value because they reduce or relieve pain without causing a loss of consciousness. They also relieve cough, spasm, fever and diarrhoea.

Opium is used as a narcotic, sedative, antispasmodic, hypnotic, sudorific and anti-diarrhoeal. The opium is official in pharmacopoeias of several countries. Opium tincture and camphorated opium tinctures are the most generally used in dosage forms for coughs. Suppositories of opium with lead are employed to relieve rectal and pelvic pains and ointment of opium with gall is applied in haemorrhoids. Opium is also used in veterinary practice.

22.3.2 Poppy seed

Poppy seeds are free from narcotics and are highly nutritious and taken by preparing various preparations. Poppy seeds are tiny, kidney shaped, generally white, occasionally red or pink to grey. They are attached to the lateral projections from the inner walls of the capsules and are produced in abundance. The seeds have well developed endosperm filled with aleurone grains. About 3300 seeds weigh 1 gm (Husain and Sharma, 1983). The poppy seeds do not contain opium.

Poppy seeds are devoid of any narcotic compounds, but have high nutritive value and are used as a food and a source of edible oil. They are used in breads, curries, sweets and confectioneries. Analysis of Indian poppy seeds showed moisture 4.3–5.2%, protein 22.3–24.4%, crude fibre 4.8–5.8%, calcium 1.03–1.45%, phosphorus 0.79–0.89% and iron 8.9–11.1 mg/100 g. Seeds also contain thiamine, riboflavin, nicotininc acid and lecithin. Minor minerals in the seeds include iodine (6 μg/kg).

The seeds have a high protein content, the major component being globulin which accounts for 55% of the total nitrogen. The amino acid make-up of the globulin is similar to that of the whole seed protein and is as follows, arginine (10.41%), histidine (2.9%), lysine (1.5%), methionine (2.3%), theonine (4.2%) and valine (7.1%). The protein are deficient in lysine and methionine. At 10% level of intake they have a biological value of 57.5% and digestibility coefficient of 81%.

The oil cake after extraction of oil from seeds contains about 32.5% protein and is used as a concentrate in feeding pigs and other animals reared for meat. Poppy seeds are utilized as food and as a source of fatty oil. They are considered to be highly nutritive and used in breads, curries, sweets and confectionery. Seeds are demulcent and are used in the form of emulsion as an emollient and as specific against obstinate constipation and in catarrh of the bladder. The whole seeds are sometimes used in pharmaceuticals.

22.3.3 Seed oil

Poppy seeds contain 50% of edible oil with a pleasant aroma and taste like almond oil. The oil is a rich source of linoleic acid (68%) which makes it a good oil for nutrition, as a high percentage of linoleic acid is desirable for lowering the cholesterol content in the human system and thus prevent coronary heart trouble. Seeds from capsule which have not been sacrificed for opium give a higher yield of oil than from those sacrificed. Poppy seed oil is used widely for culinary purposes. It is free from narcotic compounds and used as a cooking medium or as salad oil. It is free from narcotic properties. It is mixed with olive oil and used as a salad oil. It has a high digestibility coefficient of about 96% at a daily intake of 50 g. On hydrogenation, it yields a product similar to groundnut oil, which may also be useful for industrial purposes. The chemical composition of seed oil of Indian poppy is reported by Singh *et al.* (1999) as follows:

Palmitic acid (16:0): 8.90–21.48%
Stearic acid (18:0): 1.40–10.80%
Oleic acid (18:1): 13.22–36.79%;
Linoleic acid (18:2): 41.00–60.00%;
Linolenic acid (18:3): 0.00–9.40%
Manganese (29 mg/kg)
Copper (22.9 mg/kg)
Magnesium (15.6 g/kg)
Zinc (130 mg/kg).

In India the oil is expressed by the cold process, the yield being about 90%. In France, three stages are observed.

1. First cold expression – a very superior oil used for the table purposes and in the manufacture of very high quality paints
2. Second cold expression – lower grade edible oil also used for paints and illumination
3. Third hot expression – a much inferior oil to either of the others used chiefly in soap making.

The oil is rendered perfectly colourless by exposure to sun. Although both white seeded and black seeded are used for oil pressing, black seed is mostly preferred.

Cold pressing seeds of fine quality yields 30 to 40% of virgin white oil, a transparent limpid fluid with a slight yellowish tinge, bland and pleasant to taste and with almost no perceptible odour. On second pressure with the aid of heat an additional 20% to 25% of inferior oil is obtained. This oil is somewhat reddish in colour and possesses a biting taste, and a linseed-like smell. Poppy seed oil has specific gravity (15º/25ºC): 0.924–0.927, and refractive index 1.467 to 1.47, iodine value 132–142; sap value 188–196, and acid value 3.13%.

Banerji *et al.* (1999) studied and characterized the unsaponified matter of the seeds of poppy and found a total of 15 constituents of which seven major constituents were identified. Sitosterol was found to be the major constituent (59.2%) followed by campsterol (14.2%), avenasterol (7.2%), cholestanol (4.9%), stigmasterol (2.5%), cholesterol (0.6%) and D7-campsterol (0.9%).

22.3.4 Capsule husk

Capsule husk is used in tea. Bonda Chai (Bonda tea), prepared by powdered capsules and then brewed with tea, has been prevalent in Punjab and Madhya Pradesh, mainly among

truck and lorry drivers and farm labour. Poppy tea has been a common home remedy for many hundreds of years in Europe and is still practised in many of these countries. It is considered to be helpful in detoxing the heroin addiction.

To make poppy tea, after removing the seeds the poppy capsules are powdered in a coffee grinder or spice grinder into a fine powder. The powder is added to boiling water and stirred into a brew. The brew is left to cool while stirring occasionally and then filtered through a wire mesh strainer. The liquid thus obtained is bitter and taken with licorice or mixed with tea. Stem ground powder is also used to make poppy tea. The leftover pulp can be used again to make another cup of tea by adding boiling water.

22.3.5 Other parts of poppy plant

Poppy straw (unlaced capsule) has been made use of in Europe and other places as a source of morphine where it is cultivated mainly for seed and oil. Poppy plants are used in production of paper-pulp to make handmade boards. Poppy plants are sometimes eaten like lettuce leaves. It is grown as a pot herb in Iran. The red poppy flowers are used in medicine for making syrup. The red and lilac flower contains a colouring matter and are suitable for use as indicator. Poppy leaves were at one time in the French Pharmacopoeia. It contains morphine (0.03–0.2%) and other alkaloids in small quantities.

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23

Rosemary and sage as antioxidants

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23.1 Introduction

Rosemary is one of the most effective spices, widely used in food processing. It is the only spice commercially available for use as an antioxidant in Europe and the United States. One of the main potential uses is the suppression of warmed over flavour (WOF).[1] However, because of their prime use as flavouring agents, rosemary extract products are not technically listed as natural preservatives or antioxidants.

23.2 Extraction methods

The first use of an extract of rosemary leaves as an antioxidant was reported by Rac and Ostric-Matijasevic in 1955.[2] Berner and Jacobson[3] obtained a patent in 1973 for production of an antioxidant extract from rosemary using oil as a solvent. Chang *et al.*[4] reported a process for the extraction of rosemary and sage, followed by vacuum steam distillation in an edible oil or fat to obtain a colourless, odourless natural antioxidant. Bracco *et al.*[5] described an extraction process using peanut oil, followed by micronization, heat treatment and molecular distillation. Inahata *et al.*[6] obtained a patent in 1996 for production of odourless and safe antioxidants from rosemary by repeated extraction, evaporation, purification and dissolving procedures. More recently another technique, supercritical carbon dioxide extraction, has been used to product extracts of rosemary and sage.[7,8]

23.3 Antioxidant properties

Antioxidant properties of rosemary have been well documented.[9–15] Rosemary was considered both lipid antioxidant and metal helator.[12] Rosemary extract was found also to scavenge superoxide radicals.[15] The application of rosemary extracts in food has resulted in a variability in the results depending on the test model being used.

Many different solvents have been used for the extraction of the antioxidative compounds.[4,16-19] Chang *et al*.[4] extracted rosemary leaves with hexane, benzene, ethyl ether, chloroform, ethylene dichloride, dioxane and methanol. The extracts (0.02%) were tested during oxidation of lard at 60ºC in the dark. It was established that the greatest antioxidant activity was located in the methanol extract. The methanol extract was further purified, and the resultant fraction showed an outstanding activity in potato chips fried in sunflower oil and held at 60ºC in the dark for 60 days.

Marinova *et al*.,[17] Chen *et al*.,[18] and Pokorny *et al*.[19] found that the hexane extracts from rosemary were better antioxidants for lard,[17,18] rapeseed and sunflower oils,[19] than methanol[18] or ethanol[19] extracts. Hexane extract (0.05%) caused a 35-fold increase of the oxidation stability of lard determined at 100ºC, and the use of 0.05% ethanol extract resulted in a 20-fold increase.[17] In bulk rapeseed oil hexane extracts from rosemary and sage were also more efficient than ethylacetate or acetone extracts.[20] It was established that rosemary extracts were more active than sage extracts,[19,20] and that rapeseed oil was more efficiently stabilized than sunflower oil.[19]

The antioxidative effect of rosemary ethanol extract on butter,[21, 22] as well as on filleted and minced fish during frozen storage was studied.[23] Rosemary antioxidants were found suitable for deep frying in edible oils,[24] especially in the presence of ascorbyl palmitate.[25] Reblova *et al*.[26] investigated the effect of acetone and ethyl acetate extracts on the changes in rapeseed oil and in an oil containing polysiloxanes during frying of potatoes. The authors established that the rosemary extract inhibited the formation of polar substances, polymers and decomposition of polyunsaturated triacylglycerols, especially in the case of rapeseed oil, and improved the sensory attributes of French fries.

Barbut *et al*.[11] studied the effectiveness of rosemary oleoresin (RO) in turkey breakfast sausages. The authors found that RO was as effective as the combination of BHA, or butylated hydroxytoluene (BHT), with citric acid in suppressing oxidative rancidity. A standardized RO has many different phenolic components. It is thought that they act in synergy to provide antioxidant activity.

Results from the oxidation of stripped soybean oil exposed to fluorescent light, in the presence of rosmariquinone (RQ) and RO[27] indicated that RO contained compounds, such as chlorophyll, pheophytin and mono- and diglycerides, which under light interfere with the antioxidant components, thus reducing the antioxidant activity. This was confirmed by the highest level of antioxidant activity exhibited by the RQ in comparison to RO.

Lai *et al*.[28] and Murphy *et al*.[29] investigated the antioxidant properties of RO alone or in combination with sodium tripolyphosphate (STPP) in controlling lipid oxidation in restructured chicken nuggets[28] and in precooked roast beef slices[29] during refrigerated and frozen storage. Stoick *et al*.[30] studied the oxidative stability of restructured beef steaks processed with RO, tertiary butylhydroxyquinone (TBHQ), and STPP. They found that the addition of RO gave no benefit over STPP. The RO/STPP combination was equivalent to TBHQ/STPP treatment in preventing oxidation.

Wada and Fang[31] observed a strong synergistic effect between rosemary extract (0.02%) and α-tocopherol (0.05%) in sardine oil at 30ºC and in frozen-crushed fish meat models. The authors suggested that rosemary extract functions as a hydrogen atom donor regenerating the α-tocopheroxyl radical to α-tocopherol. Synergistic effects were also found between rosemary and sage extracts, and tocopherols or soybean meal hydrolysates in a linoleic acid emulsion.[32]

Basaga *et al*.[15] reported that rosemary extract and BHT, when added as mixtures of 75:25, 50:50 and 25:75 had a synergistic effect on preventing oxidation of soybean oil. A very pronounced synergistic effect was seen between citric acid and rosemary extract.[33]

23.4 Chemical structure

Concurrent with the evaluation of rosemary extracts as antioxidants to inhibit lipid oxidation in food systems, research was also focused on isolation, identification and testing of the active compounds contained in the extracts. In a study of 16 compounds isolated from rosemary Bracco *et al*.[5] concluded that the antioxidant activity of rosemary extracts is primarily related to two phenolic diterpenes, carnosol and carnosic acid. This conclusion was confirmed by other investigators.[18,34] Nakatani and Inatani[35] identified rosmanol and carnosol and found that both were more effective than α-tocopherol, BHT and BHA. The same authors also isolated rosmadial from rosemary.

Several other antioxidative diterpenes such as epirosmanol and isorosmanol,[36] rosmaridiphenol[37] and rosmariquinone[38] have been reported to contribute to the antioxidant activity of rosemary extracts. During the storage and extraction of rosemary carnosic acid is partially converted either into carnosol or into other diterpenes such as rosmanol.[5,39–41]

Rosmarinic acid (RA) was reported by Gerhardt and Schröter[42] to be the second most frequently occurring caffeic acid ester, following chlorogenic acid, and to have antioxidant activity equivalent to that of caffeic acid. The authors detected RA in rosemary, balm, sage, thyme, oregano, marjoram, savory, peppermint, and for the first time in basil.

There are many data in the literature concerning the antioxidative properties of the individual compounds isolated from rosemary. Brieskorn and Domling[43] showed that carnosic acid and carnosol were as effective as BHT and that their effectiveness was concentration dependent. The authors noted that the activity of both compounds was due to the cooperation of their *ortho* phenolic groups with their isopropyl group.

It was also reported that rosmanol had greater antioxidant activity than carnosol,[35] with carnosic acid being more potent than carnosol.[40,44] In soybean oil carnosic acid was found to be more active than BHT and BHA, but less active than TBHQ. Carnosic acid and carnosol showed the ability to chelate iron and were effective radical scavengers of peroxyl radicals.[34] It has been established[17] that the molecules of carnosol and the radicals formed from them participate in the reactions of chain initiation and propagation to a much lower degree than is the case with most natural and synthetic antioxidants.

Houlihan *et al*.[37] found rosmaridiphenol to be more active than BHA in lard and equivalent to BHT in this test system. They reported also that RQ was superior to BHA and equivalent to BHT in controlling the oxidation of lard.[38] RQ has been shown to have good antioxidant activity also in soybean oil.[27] Hall *et al*.[45] proved that RQ acted as a hydrogen-donating antioxidant. Isorosmanol and epirosmanol showed high activity in both lard and linoleic acid;[36] in lard they were four times more active than BHA and BHT. Nakamura *et al*.[46] reported that RA exhibited a significantly higher superoxide scavenging activity than ascorbic acid.

As far as the complex food systems are concerned, it is important to clarify the antioxidative behaviour not only in bulk oil, but also in oil-in-water emulsions,[47-49] as well as in microsomal and liposomal systems.[34] Frankel *et al*.[47] reported that in bulk corn oil rosemary extract, carnosic and rosmarinic acids were significantly more active than carnosol. In contrast, in corn oil-in-water emulsion, the rosemary compounds were less active than in bulk oil, and the rosemary extract, carnosic acid and carnosol were more active than rosmarinic acid. The decreased antioxidant activity of the polar hydrophilic rosemary compounds in the emulsion system may be explained by their interfacial partitioning into water, thus becoming less protective than in the bulk oil system.[47]

Carnosol and carnosic acid were powerful inhibitors of lipid peroxidation in microsomal and liposomal systems.[34]

Cuvelier *et al*.[50] found no correlation between the antioxidative effectiveness of the rosemary extracts from different pilot-plant or commercial sources and their composition in 20 specific phenols, a finding which illustrates the complex influence of the various factors on lipid oxidation stability.

23.5 Sage: antioxidant properties

Salvia officinalis L, commonly known as sage (Dalmatian sage), is used in foods for flavouring and seasoning. It was found that, along with rosemary, it had the best antioxidant activity among the numerous herbs, spices and teas tested.[33,51] Its extracts are also well known as efficient antioxidants.[33,50-53]

Since methanol and ethanol were found to be the most suitable solvents for extraction of antioxidants from the plant materials, a number of publications have dealt with further purification of the alcohol extracts. Vacuum steam distillation[4] or molecular distillation[5] are recommended for use on production scale.

Since rosemary and sage belong to the *Labiatae* family, it is not surprising to find the same antioxidants in both plants: carnosol,[50,54] carnosic acid,[40,43,55-57] rosmanol,[50,57] rosmadial,[50] rosmarinic acid.[56] Various methyl and ethyl esters of carnosol, rosmanol, and carnosic acid can be found in sage, as well as in other *Labiatae* plant extracts; in most cases the compounds are believed to be artefacts from the extraction procedures.[39,40,43] The main antioxidative effect of sage was reported to relate to the presence of carnosic acid, carnosol and rosmarinic acid.[50,56]

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24

Saffron

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24.1 Introduction

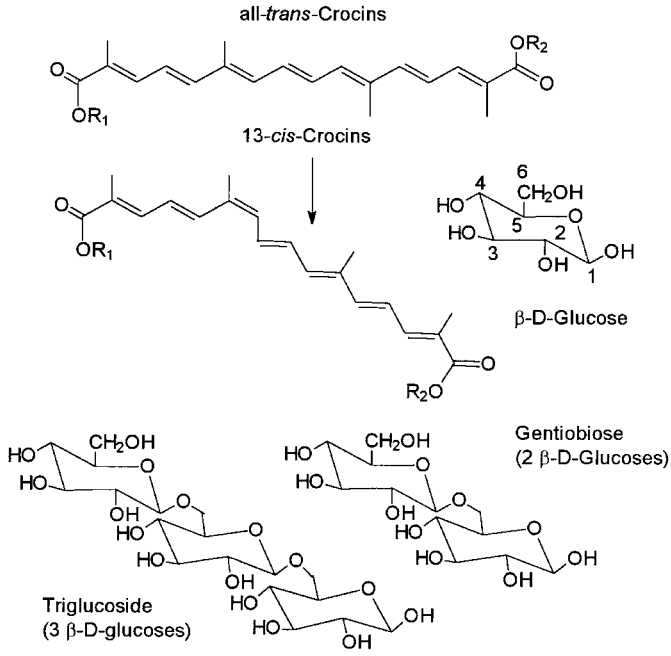
Saffron, the most expensive spice in the world, is derived from the dry stigmata of the saffron crocus *Crocus sativus* L., a member of the family *Iridaceae*. The plant is a sterile autotriploid cultigen, 2n = 24, possibly selected from *C. cartwrightianum* Herbet, of Greek origin. The family *Iridaceae* is included in the order Liliales, subclass Liliidae (Monocots), and is divided into four subfamilies; *Crocus* L. belongs to subfamily *Ixioideae* tribe *Ixieae*.[1] *C. sativus* is a plant of 10–30 cm and has a corm-tunic finely fibrous; the fibres reticulate. It has 6–10 leaves present at anthesis, 1–2 flowers of a lilac-purple colour, with perianth segments of 3.5–5 cm and style branches of 2.5–3.2 cm. The yellow style is deeply divided into three branches, and the stigmata are bright red. The flowering season is from October to December.[2]

The first mention of the crop of saffron dates back to 2300 BC. Sargon, founder of the Accadian empire, was born at an unknown village, the City of Saffron, 'Azupirano', near the river Euphrates in Babylon. The 'Harvester of saffron' appears in the Minoan pottery and frescoes (1700–1600 BC) of the Palace of Minos in Knossos (Crete). Another fresco dated about 1500 BC is at Akrotini on the Island of Thera (Santorini). 'Krokos' was the Greek word for saffron and appears in the songs IX and XII of the Iliad by Homer. In Greek mythology, Krokos, the lover of nymph Esmilax, was transformed into the plant saffron by Hermes. Saffron was also known in ancient Egypt and mentioned in the Eber's papyrus. In the Bible, saffron was 'karkon' (in Hebrew) and is referred to in the Song of the Songs (4:14) of King Solomon X or IX century BC. There is evidence of its medicinal use in Kashmir in 500 BC.[3] The word saffron is derived from the arabic word 'Za.feraan' and the Arabs are sometimes credited with the introduction of saffron in Spain around the tenth century.

24.2 Chemical structure

In ancient times saffron was an important dye, but nowadays its main uses are cooking and colouring foods, especially Spanish rice (paella), bouillabaisse and in Cornwall,

traditional saffron cakes and loaves. The major components responsible for the colouring strength of saffron are *cis* and *trans* crocins. Crocins are unusual water-soluble carotenoids. With concentrated sulphuric acid their red colour changes to blue (polychroit). The molecular formula of the most common crocin (a digentiobiosyl ester of crocetin) is $C_{44}H_{64}O_{24}$. This crocin is a bis-(6-O-β-D-glucopyranosyl-β-D-glucopyranoside) ester of crocetin (= di-(β-gentiobiosyl)-crocetin), $C_{20}H_{24}O_4$ a carotenoid 8,8′-diapo-ψ, ψ′-carotendioic acid (*trans*-crocetin). In addition to crocin there are some more esters (all-*trans* and 13-*cis* isomers) of crocetin in saffron (Fig. 24.1). Crocins are produced in the plant kingdom from a glucoside derivative of zeaxanthin (all-*trans*-β-carotene-3,3′-diol, $C_{40}H_{56}O_2$) named protocrocin, which by enzymatic oxidative degradation (Fig. 24.2) produces one molecule of crocin and two molecules of picrocrocin, the substance responsible for saffron's bitter taste. Crocins have also been found in the fruits of *Gardenia jasminoides* Ellis (Rubiaceae), in *Nycthanthus arbor-tristis* L. (Oleaceae) from India, in *Crocus albiflorus* Kit var. *neapolitanus* Hort., and in *C. lutens* Lam.[4–6]



Crocin A	R_1=R_2 = Gentiobiose MW 976
Crocin B	R_1 = Gentiobiose; R_2 = Glucose MW 814
Crocin C	R_1 = Gentiobiose; R_2 = H MW 652
Crocin D	R_1 = R_2 = Glucose MW 652
Crocin E	R_1 = Glucose; R_2 = H MW 490
Crocin F	R_1 = Triglucoside; R_2 = Gentiobiose MW 1138
Dimethylcrocetin	R_1 = R_2 = CH_3 MW 360
Crocetin	R_1 = R_2 = H MW 328

Fig. 24.1 The crocins. All-*trans*-crocins and 13-*cis*-isomers. (Adapted from Tarantilis P A *et al.*, *J Chromatography*, 1995 **699** 107–18.)

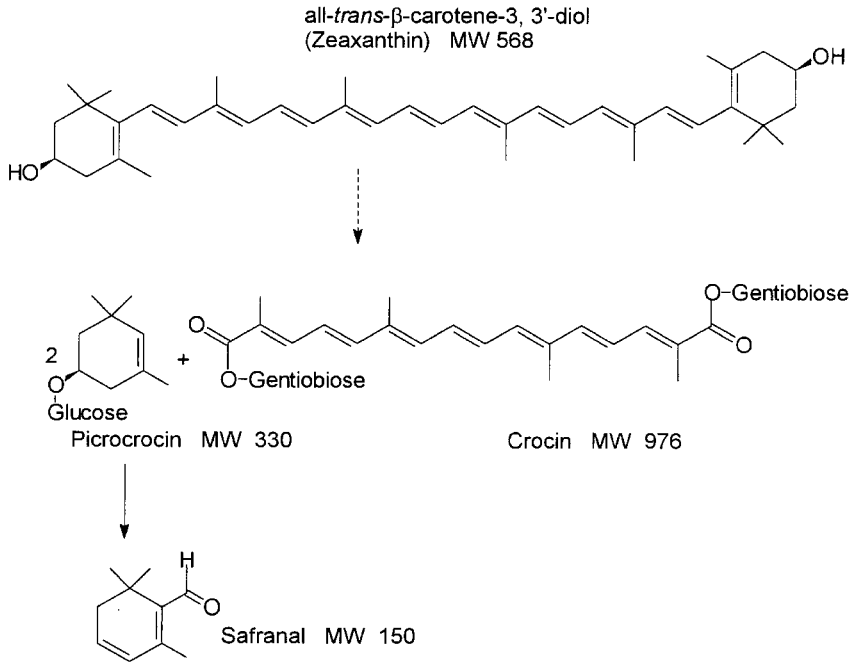


Fig. 24.2 Biosynthesis of crocin, picrocrocin and safranal.

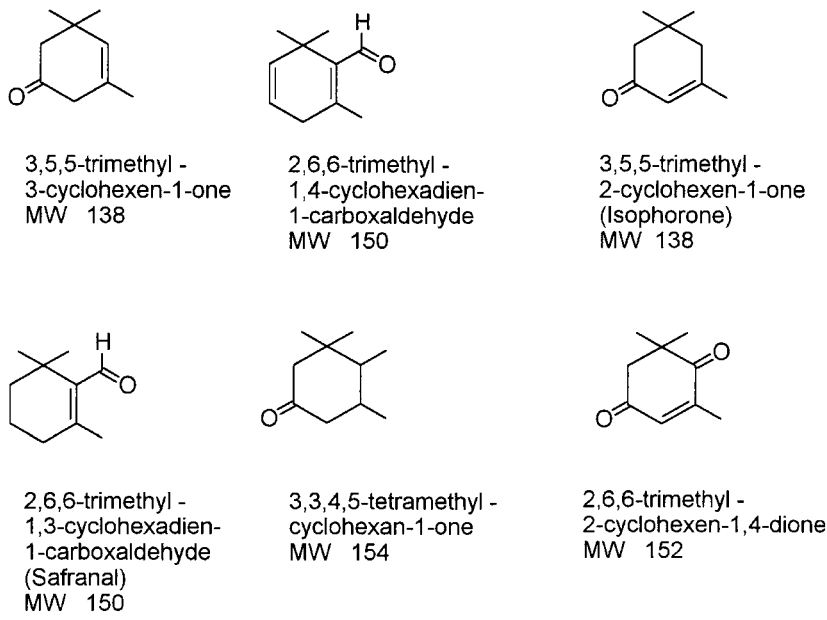


Fig. 24.3 Characteristic cyclohexane derivatives of saffron's aroma. (Adapted from Tarantilis *et al.*, *J Agric Food Chem*, 1997 **45** 459–62.)

Picrocrocin or saffron bitter $C_{16}H_{26}O_7$ (R-4-(β-D-glucopyranoxyloxy)-2,6,6-trimethyl-1-cyclohexene-1-carboxaldehyde), is responsible for the bitter taste of the spice. By submitting picrocrocin to hydrolysis and dehydration, safranal, the principal substance responsible for the aroma of saffron, is obtained. Safranal ($C_{10}H_{14}O$) corresponds to 2,6,6-trimethyl-1,3-cyclohexadiene-1-carboxaldehyde (= β-dehydrocyclocitral). By enzymatic hydrolysis of picrocrocin with a β-glucosidase, 4-OH-β-cyclocitral is produced and this component gives safranal by dehydration. The essential oil obtained by hydrodistillation of saffron contains safranal as main constituent and many other derivatives of cyclohexane (Fig. 24.3). In addition to crocin, safranal and picrocrocin, Spanish saffron with a water content of 15.6% contains protein (10–14%), sugars (13–14%), starch (6–7%), gums and dextrin (9–10%), pentoses (6–7%), ash (5–8%), fibre (4–5%), volatile oil (0.8%), fatty oil (8–13%) with glycerin esters of palmitic, stearic, lauric, and oleic acids; 56–138 γ/g vitamin B_2, 0.7–4.0 γ/g vitamin B_1 xanthophylls, carotenes (α, β and γ), lycopine and zeaxanthin; Ca (111 mg), Fe (11.1 mg), P (252 mg), Na (148 mg), K (1724 mg). Saffron is the richest known source of vitamin B_2.[4–7]

Picrocrocin and crocin are easily oxidized by direct contact with oxygen in the air. As saffron is used chiefly as a food additive for flavouring and colouring, the process of autooxidation is undesirable. Samples of saffron stored at 0ºC and −17ºC and 0% relative moisture showed no change in crocin and picrocrocin content. Therefore, low moisture content and low temperature are the best storage conditions. The colouring strength and bitter taste of dehydrated saffron are five times more concentrated than those of fresh saffron.[8,9]

24.3 Production

At present, the major saffron cultivating countries for trade are Spain, Iran, Greece, India, China and Morocco. Minor producers are Italy, Switzerland, France, Argentina and Azerbaijan. The spice is also produced in the southern hemisphere in New Zealand.[10] In Spain the crop of saffron is of considerable importance, and it is mainly grown in the provinces of Albacete, Ciudad Real, Cuenca and Toledo (La Mancha region, southeastern Spain) and also in Teruel. One of the best quality saffrons are those harvested in La Mancha, traditionally regarded as 'Saffron Mancha' or 'Azafrán Mancha'. Saffron in Spain is harvested and processed according to the following process.[11]

The corms are planted in furrows. There are two rows of corms in each furrow and the depth of the furrow is 12–15 cm. The distance between furrows is 25–30 cm. The space between corms in a row is 10 cm and the distance between rows in each furrow is 8–10 cm. The planting season is from July to September. Large amounts of organic manure are incorporated into the soil before planting the corms. The artificial fertilizers used are a mixture of potassium sulphate and ammonium nitrate. In Spain, saffron is grown in dry temperature conditions (dry farming), but irrigation in March, April and August is frequent. In Spain the major pest is the common vole (a field mouse). Farmers usually fumigate their burrows or use traps to solve the problem. In other countries, rabbits are also a major pest problem. Rabbit-proof fencing may be required in areas where these pests are found. Saffron can suffer from a range of diseases, especially several fungi such as *Rhizoctocnia* and *Sclerotinia* (*Phoma*). Dipping corms in fungicide before planting, and using raised beds to improve drainage help minimize these problems. No herbicides have been tested for weed control in actively growing saffron.

Saffron is hand-harvested at the flowering season (still the only method for harvesting the crop) at the end of October and beginning of November. The process of picking the stigmata is done on the same day as harvesting. Once the stigmata have been separated from the flowers, careful drying is needed to produce a product of good quality. In Spain the traditional method involves gently toasting the stigmata in a silk sieve over the embers of a charcoal fire. The loss of weight in this process is about 80% with respect to fresh weight of stigmata. The final product may be stored in paper, cloth or plastic containers. In other countries, Iran for example, saffron is prepared by removing the whole style with the stigmata binding them together in bunches and sun drying. In New Zealand, saffron is dried in an airflow oven at 30ºC for 34 hours.[10, 11]

Most commercial production of saffron occurs in Spain and Iran. Saffron is grown successfully under rain-feed conditions in Kashmir (India), with an annual rainfall of 1000–1500 mm. Spring rain is favourable for corm production while rain immediately before flowering encourages high flower yield. Average yields of saffron in Spain and other commercial values, can be seen in Table 24.1.[12] In Kashmir the yield amounts to only 1.5–3.0 kg/ha (average). Between 70 000 and 200 000 flowers are needed to produce 1 kg of dried saffron threads. In New Zealand the rate is 165 000–151 000 flowers/kg of dried saffron.[10, 11] In India, the total production of saffron rose from 5 t in 1974 to 10 t in 1983. Iran is another major producer, growing 50 t of spice in 1989. Iran uses 10–15 t in its domestic market and the rest is exported to Spain. Spain re-exports this product together with its own. Overall Spanish production is in decline mainly due to increasing labour costs and the unwillingness of young people to enter the industry. It is worth remembering that if one stigma of saffron weighs about 2 mg and each flower has three stigmata, 150 000 flowers must be carefully picked by hand one by one to obtain one kg of spice. The price on the international market is ca US$1000/kg. Retail prices, naturally, are much higher. For instance, the price of an envelope of 250 mg saffron in Spain is 260 pesetas, equivalent to 1 040 000 pesetas/kg (10–15 US$/1 g).[10–12]

Table 24.1 Commercial values of Spanish toasted saffron

Year	Area (ha)	Yield (kg/ha)	Production (kg)	Field price (euro)/ kg	Price (euro) Millions of euros	Import (tm)	Export (tm)
1985	4,233	6.18	26,145	417	11.023	–	34
1986	4,067	8.74	35,537	422	15.067	–	34
1987	4,209	8.21	34,556	532	18.181	1	–
1988	4,229	4.82	20,374	662	13,487	2	–
1989	4,193	6.12	25,671	701	18,000	9	44
1990	3,696	5.89	21,789	613	13.348	7	31
1991	3,298	7.17	23,654	530	12.543	11	35
1992	2,582	5.23	13,500	493	6.647	12	207
1993	1,878	7.80	14,642	466	6.815	26	212
1994	1,406	6.71	9,431	491	4.628	23	64
1995	1,163	5.47	6,365	563	3.582	28	46
1996	1,020	5.43	5,541	605	3.348	–	–

Tm = metric ton; 1 euro = 166. 386 pesetas; ha = hectare
Source: Anuario de Estadística Agraria, MAPA, Servicio de Estadísticas Agrarias, Madrid (Spain), 1997. Adapted into English.

24.4 Uses

In modern times saffron is used almost exclusively as a culinary seasoning and to colour foods. The range of foods that have been spiced with saffron is wide, including cream or cottage cheese, bouillabaise, chicken and meat, rice, mayonnaise, liquors and cordials. Spanish, Italian and French cuisine favours the use of saffron. An example is rice ('Spanish paella and Zarzuela de pescado') in the Spanish cuisine or 'Rissotto à la Milanesa' an excellent Italian dish. It is often used in chicken and fish dishes. When using saffron threads, the recipe preparation must start steeping the stigmata to extract their essence for a minimum of 20 minutes in addition to cooking/baking time. This can be done in alcohol, an acidic liquid or hot liquid.[3, 13, 14]

However, saffron has found its way into the cuisine of many European and Asian countries, especially in festive fare. Special Christmas bread and buns using saffron are traditional in Sweden. Saffron cakes are another speciality in parts of England. It is an essential commodity in high-quality, milk/cream-based confectioneries and Mughlai dishes in India wherein it imparts a rich colour and distinctive flavour. The average use of this spice in weddings in even a middle-class Indian family in the states of Rajasthan and Gujarat is about 250 g. In the western world, although its major use is as a spice, it is also employed as a health tonic without side effects. About 50 mg of saffron dissolved in a 200 ml glass of milk and a spoonful of sugar makes a very tasty drink which is also a health tonic. In Arab countries visitors are welcomed with a drink prepared from coffee, saffron and cardamom. In Japan it is employed to enhance the taste of fish and give it a golden-yellow colour.[13, 14] In the food industry it is one of the ingredients in dehydrated foodstuff mixes, soups, ice cream and many other processed food products. Is also used, mainly in India, as a key ingredient in flavoured chewing tobacco as saffron enhances its taste to a great extent.[13, 14]

Water-soluble crocins are the main pigments responsible for the colouring strength of the spice. In the ancient world, pigments used as dyes and colouring matters were rare and very expensive and were considered as status symbols often reserved for royalty. The saffron mantle of the Kings of Ireland and saffron-dyed material supplied by the Phoenicians to the Kings of Assyria are good examples. In order to dye wool or silk with saffron the material must first be mordanted with alum and then soaked into the dye solution until the desired colour is obtained. However, the use of saffron as a dye has now been superseded by synthetics because of the high price of the spice. Scientifically, saffron has been employed as an histological stain as a dye for connecting tissues. It has also been reported that saffron was used as a glaze on burnished tint oil as a cheap but effective substitute for gold in medieval illumination.[3, 13, 14]

Saffron is also used as a perfume and in cosmetics. Safranal, a pleasantly odoriferous component of saffron develops during the process of drying by hydrolysis of the bitter substance picrocrocin, which is present in the fresh stigmata. The Greeks considered saffron as a sensual perfume. It was strewn in Greek halls, courts, theatres and in Roman baths. In Rome the streets were sprinkled with saffron when Nero entered the city. In the Middle East saffron is used to prepare an oil-based perfume called 'Zaafran Attar', which is a mixture of saffron and sandalwood. An alcoholic tincture of saffron is sometimes used as a fragrance ingredient particularly in oriental-type perfumes. Saffron is used as a perfume ingredient in many famous perfume brands The spice is also employed in some types of incense. Nowadays the use of saffron in the cosmetic industry is increasing owing to its active substances and to the trend to use natural products in cosmetic formulations.[3, 13, 14]

24.5 Functional properties

The Ebers papyrus (*ca* 1550 BC) mentions saffron as an ingredient in a cure for kidney problems. Hippocrates, Theophrastus and Galen considered it to be an appetite stimulant, an aid for easing digestive disorders and praised its calming effects on infants.[3] Saffron is an often quoted folk remedy for various types of cancer.[7] Extracts of saffron have been reported to inhibit cell growth of human tumour cells. Crocins, the water-soluble carotenoids of saffron, are the most promising components of the spice to be assayed as a cancer therapeutic agent.[15] Due to the presence of crocetin it indirectly helps to reduce cholesterol levels in the blood. This finding was connected with the low incidence of cardiovascular disease in parts of Spain where saffron is liberally consumed almost daily.[3] In small doses it is considered anodyne, antihysteric, antiseptic, antispasmodic, aphrodisiac, balsamic, cardiotonic, carminative, diaphoretic, ecbolic, emmenagogue, expectorant, nervine, sedative, stimulant, and stomachic.[7]

In India saffron is used as a herb in Ayurvedic medicines which heal a variety of diseases ranging from arthritis to impotence and infertility. Saffron is also employed to cure asthma and coughs, useful for colds, to treat alcoholism and to treat acne and skin disorders. It is known to have aphrodisiac properties and is widely employed in Asia and the Middle East as such. Chinese and Tibetan medicine also find many uses for saffron. In India, the spice is used for bladder, kidney and liver ailments and also for cholera.[14] Mixed with 'ghee' it is used for diabetes.[7] In Indian Unani medicine it is used to reduce inflammation, for treatment of enlarged liver and in infection of the bladder and kidneys. As an ingredient in recipes it is useful in menstrual disorders, for strengthening the heart and as a refrigerant for the brain. If soaked overnight in water and administered with honey it acts as a diuretic. Pounded with clarified butter it used for treating diabetic patients.[14] Saffron blended with opium, cinnamon and clove, commonly known as 'laudanum' was once used as an analgesic and antidiarrhoeic agent.[16] Also mixed with cinnamon, orange peel, rose petals, honey and egg yolk it was employed in ancient Iran as a tonic to restore the strength of the body.[17] Preparations based on the stigmata may be used topically to relieve teething pains in children. Overdoses of saffron (>5g) are narcotic, and saffron corms are toxic to young animals. Apoplexy and extravagant gaiety are possible aftereffects. Fatalities have resulted from the use of saffron as an abortifacient.[7]

24.6 Quality issues

The most common adulteration practices of saffron are as follows:[18, 19]

1. The place of origin is falsified. For instance, saffron from different Spanish areas or from different countries is sold as 'saffron Mancha', one of the best-quality saffrons in the world.
2. The spice is mixed with extracted saffron, old saffron or with style material from the saffron flower.
3. Other parts of the saffron flower are added, stamens or dyed perigonia cut into strips.
4. Some substances are mixed to increase the weight. Moisture, syrups, honey, glycerine, oils, barium sulphate, calcium carbonate, gypsum, potassium hydroxide, saltpeter, Glauber's salt, Seignette's salt, borax, lactose, starch or glucose are commonly used.
5. Other plants are added. These include dried petals of safflower (American or Mexican saffron, *Carthamus tinctorius* L.) and Scotch marigold (*Calendula*

officinalis L.); stigmata from other species of *Crocus,* usually shorter and without colouring properties, such as *Crocus vernus* L.and *C. speciossus* L. Flowers of poppies (*Papaver rhoeas* L.); pomegranate (*Punica granatum* L.), arnica (*Arnica montana* L.) and Spanish oysters (*Scolymus hispanicus* L.); stamens of some species of carnation (*Dianthus* sp.), ground red pepper (*Capsicum annuum* L.); herbaceous plants cut into pieces and dyed; small roots of leeks (*Allium porrum* L.), red sandalwood dust (*Pterocarpus santalinus* L.), logwood particles (*Haematoxylon campechianum* L.) and curcuma (*Curcuma longa* L.).

6. Sometimes fibres of salted and dried meat are added.
7. Artificial products such as coloured gelatin are added.
8. Organic colouring matters such as Martius yellow, tropeolin, fuchsin, picric acid and colouring products derived from tar.

As saffron is the most expensive of spices, quality control regulations have been proposed in an attempt to avoid these adulterations. The ISO (International Standards Organization) standards are the quality control regulations currently applied in the international saffron business.[20] These standards specify microscopic and chemical requirements. Aqueous extracts of saffron are submitted to spectrophotometric scan. Three maximum values are considered which, according to the ISO standards, correspond to the colouring components (crocins at 440 nm), bitter constituents (picrocrocin at 257 nm) and volatile fragrances (safranal at 330 nm). In order to improve this method, high performance liquid chromatography with photodiode array detection (HPLC-DAD) has been used to separate picrocrocin, *cis*/*trans* crocins and safranal. This method coupled with mass spectrometry is suitable for the determination of picrocrocin, safranal and

Table 24.2 ISO standards 3632-1 1993, Chemical requirements

Specifications	Stigmata	Powdered
Total ashes (%) (w/w), dry matter, max.	8	8
Moisture and volatiles (%) (w/w), max.	12	10
Insoluble ashes in acids (%) (w/w), dry matter, max.		
Categories I and II	1.0	1.0
Categories III and IV	1.5	1.5
Water solubility (%) (w/w), dry matter, max.	65	65
Bitterness, picrocrocin absorbance at 257 nm, dry matter, min.		
Category I	70	70
Category II	55	55
Category III	40	40
Category IV	30	30
Safranal absorbance at 330 nm, dry matter, all categories		
Min.	20	20
Max.	50	50
Colouring strength, crocins absorbance at 440 nm, dry matter Min.		
Category I	190	190
Category II	150	150
Category III	110	110
Category IV	80	80
Crude fibre (%) (w/w), dry matter, max.	6	6
Total nitrogen (%) (w/w), dry matter, max.	3.0	3.0

Source: Adapted from International Standards Organization, Geneva, 1993.

Table 24.3 Spanish specifications of saffron for foreign trade (August 1999)

Standards	Minimum	Maximum
Moisture and volatiles, 100–105ºC (%) (w/w) dry weight	–	15
Total ashes (%) (w/w), dry matter	5	8
Insoluble ashes in ClH (%) (w/w), dry matter	–	2
Ether extract (%) (w/w), dry matter	3.5	14.5
Colouring strength ($E^{1\%}$), absorbance at 440 nm		
Fine or superior saffron	180	–
Saffron Rio	150	–
Saffron Sierra	110	–
Saffron 'standard'	130	–
Saffron Coupé	190	–

Source: Normas de calidad del Comercio Exterior para el Azafrán. Ministerio de Economís y Hacienda de España. Adapted into English.

flavonoids and is the technique of choice for the analysis of crocetin glucosides with one to five glucoses and differentiation of their *cis*/*trans* isomers.[21–23] Methods for the analysis of the aromatic components of saffron have been developed. The best techniques were shown to be headspace chromatographic methods and thermal desorption gas chromatography on line with mass spectroscopy (TD-GC/MS).[19, 24, 25]

Saffron is classified according to ISO standards (Table 24.2) in four categories on the basis of its floral waste, extraneous matter contents and chemical requirements. Some researchers have demonstrated that colouring strength is the main characteristic to define saffron's categories. Moreover it has been shown that if colouring strength fits with the regulation for a certain category, the other requirements fit too. In Spain the standards that control the quality specifications for saffron foreign trade are listed in Table 24.3. It is worth mentioning that the quality category 'saffron Mancha' has been substituted for 'Azafrán selecto o superior' (fine or superior saffron). Powdered saffron must fit the above-mentioned specifications according to its category except moisture that must be less than 8%. Fine or superior saffron is defined as follows: stigmata much longer than the united styles, with an intense red colour. Maximum floral waste matter 4%.[26]

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25

Tamarind

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25.1 Introduction

Tamarindus indica L., commonly known as tamarind tree is one of the most important multipurpose tree species in the Indian sub-continent. It is a large evergreen tree with an exceptionally beautiful spreading crown, and is cultivated throughout almost the whole country, except in the Himalayas and western dry regions (ICFRE, 1993, Rao *et al.*, 1999).

The tamarind fruit pulp has been an important culinary ingredient in India for a very long time. Almost all parts of the tree find some use or other in food, chemical, pharmaceutical and textile industries, and as fodder, timber and fuel (Dagar *et al.*, 1995; George and Rao, 1997).

Tamarind is thought to have originated in Madagascar (Von Maydell, 1986; Hocking, 1993). It is now cultivated throughout semi-arid Africa and South Asia, where it has become naturalized in several regions. It has been planted extensively in Bangladesh, India, Myanmar, Malaysia, Sri Lanka, Thailand and several African, Australian, Central American and South American countries. The fruit became known in Europe during the Middle Ages. Tamarind fruit was at first thought to be produced by an Indian palm, as the name tamarind comes from a Persian word 'Tamar-I-hind', meaning date of India. Its name 'amlika' in Sanskrit indicates its ancient presence in the country (Mishra, 1997). In Myanmar it is reported as one of the commonest village trees in the dry zone (Troup, 1921). Commercial plantations are reported in Belize, Central American countries and in north Brazil (Sharma and Bhardwaj, 1997).

In India, tamarind is known by a wide variety of vernacular names: Assamese – Tetuli; Bengali – amli, nuli, textili tentul; Gujrati – amali, ambali; Hindi – ambli, amli, imli, tamarulhindi; Kannada – hunase, hunase-mara, hunse; Malayalam – puli; Marathi – amli, chinch, chitz; Oriya – koya, tentuli; Punjabi – imli; Parsian – Tamarhindi; Tamil – Puli, pulia-maram; Telugu – Chinta; Urdu – imli. In Arabic it is Tamre-Lindi, in French – tamarind, in Spanish and Portuguese – tamarindo and English-speaking people call it tamarind (Mishra, 1997).

The genus *Tamarindus* is a monotypic genus and belongs to the sub-family Caesalpinioideae of the family Leguminosae (Fabaceae). Tamarind is a moderate-sized

to large, evergreen tree, up to 24 m in height and 7 m in girth. The morphology of the tree in detail has been described by several authors (Singh, 1982; Parkash and Drake, 1985; George and Radhakrishna, 1993; ICFRE, 1993; Dubey *et al.*, 1997). The most useful part is the pod. Pods are 7.5–20 cm. long, 2.5 cm broad and 1 cm thick, more or less constricted between the seeds, slightly curved, brownish-ash coloured, scurfy. There are 3–12 seeds in each pod contained in loculi, enveloped by a tough, leathery membrane, the so-called endocarp. Outside the endocarp is the light-brownish, red, sweetish acidic, edible pulp, traversed by a number of branched, ligneous strands. The outermost covering of the pod is fragile and easily separable. The pods begin to ripen from February to April (Cowen, 1970; Duke, 1981; 1CFRE, 1993; Dubey *et al.*, 1997; Choudhary and Choudhary, 1997; Rao *et al.*, 1999).

25.2 Production

Rough estimates are available on production of tamarind in India. One estimate has production at over 3 lakh tonnes in 1994–95. Tamarind cultivation is concentrated in the states of Tamil Nadu, Andhra Pradesh, Karnataka, Orissa and Kerala (Jambulingam and Fernandes, 1986; Anon., 1997; George and Rao, 1997; Rao, 1997; Vennila and Kingsley, 2000).

25.2.1 Sources

Among 52 spices under the purview of the Spices Board (Govt. of India), tamarind occupies sixth position in terms of export earnings (George and Rao, 1997). It is exported as fresh, dry and paste. Export of tamarind seed also takes place both in unground and ground forms. Export of tamarind and seed in different forms for five years from 1992–93 is provided by Anon. (1996a, 1996b). Tamarind products are exported to around 60 countries.

Tamarind fruits begin to ripen during the months of February–March. The pods are allowed to ripen on the tree until the outer shell is dry and thereafter harvested and the shells are removed manually. The pulp is separated from the seeds and fibres and dried in the sun to reduce its moisture level. Then it is packed in palm leaf mats, gunny bags or polythene bags and stored in a dry place. The average composition of the pod is accounted as 55% pulp, 34% seeds and 11% shell and fibres (Ishola *et al.*, 1990; Shankaracharya, 1997, 1998). All these operations are manual and therefore very labour-intensive. Mechanical methods for extracting pulp (Benero *et al.*, 1972), chemical composition of juice concentrates (Nagaraja *et al.*, 1975), preservation of sweet tamarind in Thailand (Chumsai-Silavanich *et al.*, 1991) and physico-chemical composition of commercial tamarind powder (Manjunath *et al.*, 1991) have been reported.

A tamarind dehuller was designed and developed at the Post Harvest Technology Scheme (ICAR), UAS, Bangalore with a hulling capacity of 500 kg/h (Ramkumar *et al.*, 1997). The hulling efficiency of the machine developed was reported to be 80% for the large size curved fruits, while for the small fruits, the efficiency was only 58%.

Pulp loss during storage was very low in black polyethylene (0.18%) and plastic (0.17%) compared to phoenix mat (1.35%) and metal (1.53%) (Ramakumar *et al.*, 1997). Feungchan *et al.* (1996) conducted studies on factors related to colour change of tamarind pulp from brown to black to yellow in storage and recommended mixing of 10% powdered salt and cold storage to prevent this. Based on observations on post-harvest

physiological and chemical changes in tamarind fruit, Lakshminarayana and Hernandez-Urzon (1983) had suggested that tamarind may be processed within one week after harvest in order to get maximum yield.

Tamarind pulp/concentrate is one of the essential components in Indian culinary habits. It is a common article of trade and is preserved and stored for marketing in a number of ways (Lewis *et al.*, 1957; Lewis and Neelakantan, 1959, 1964; Benero *et al.*, 1972; Patil and Nadagouder, 1997). Patil and Nadagouder (1997) reported that commonly, the pulp freed from fibre and seed is mixed with 10% salt and beaten down with mallets so as to exclude air and packed in gunny bags, lined with palm leaf-matting. In another process, the salted pulp is trodden into a mass and made into balls, which are exposed to the sun and dew for about a week. Concentrates of the pulp, more or less jelly-like in consistency, are also marketed.

25.3 Main uses

25.3.1 Pulp

The fruit-pulp is the chief agent for souring curries, sauces, chutneys and certain beverages throughout the greater part of India. Tamarind fruit is also reported to be used as a raw material for the preparation of wine-like beverages (Giridharlal *et al.*, 1958; Sanche, 1985; Latino and Vega, 1986; Benk, 1987). According to the research findings of CFTRI (Central Food Technological Research Institute), Mysore, India, the pulp could be preserved well for 6–8 months, without any treatment, if it is packed in airtight containers and stored in a cool dry place (Shankaracharya, 1997). The edible portion of the ripe pod reportedly contains moisture 63.3–68.6%; protein 1.6–3.1%; fat 0.27–0.69%; total sugars 22.0–30.4%; sucrose 0.1–0.8%; cellulose 2.0–3.4% and ash 1.2–1.6%. The dried pulp contains moisture 20.9–21.3%; protein 3.1–5.0%; fat 0.1–0.6%; total carbohydrates 67.4–70.7%; fibre 5.6–18.3%; tartaric acid 8–18%; invert sugars 30–40%; ash 2.4–2.9% and 270 calories. Lewis *et al*. (1957b), Shankaracharya (1997, 1998), remarked that the sweetness of the so-called red-variety of tamarind might be due to the presence of lesser amounts of free-acids in the pulp. According to these investigators the colour of the red-tamarind pulp is due to an anthocyanin pigment called chrysanthemin. The common variety contains a leucocyanidin pigment. Nearly 60 volatile compounds have been detected in tamarind pulp (Zhang and Ho, 1990; Shankaracharya, 1998).

25.3.2 Concentrate

Juice concentrate of tamarind is produced and marketed in India and abroad (Raghuveer, 1997). The product is promoted as being very convenient for culinary purposes and the food industry. The CFTRI, Mysore, has developed processes for the manufacture of juice concentrate and powder of the pulp (Sankaracharya, 1998). Formulae for preparing spiced sauces and beverages from the pulp have also been reported (Patil and Nadagouder, 1997). The approximate composition of the concentrate according to CFTRI report is as follows: total tartaric acid 13%; invert sugars 50%; pectin 2%; protein 3%; cellulosic material 2%; and moisture 30%. Tamarind juice concentrate was found to be more viscous than sucrose solutions (Manohar *et al.*, 1991).

25.3.3 Seeds

Following the estimation of the composition of seeds and evaluation of its properties, Marangoni *et al*. (1988) opined that tamarind seeds are potential sources of food or food ingredients. They recorded that seeds formed about 35% of the whole fruit with 30% testa and 70% endosperm (kernel). When analysed seeds were found to contain 17.1–20.1% protein; 6.0–8.5% fat; 65.1–72.2% carbohydrates; 0.7–4.3% crude fibre and 2.3–3.2% ash. The chemical composition and nutritive value of tamarind seeds and kernels was determined by several workers (Bose *et al.*, 1954; York *et al.*, 1993; Siddhuraju *et al.*, 1995; Patil and Nadagouder, 1997). Bhattacharya *et al*. (1993, 1994a) reported that the kernel protein is rich in lysine, glutamic acid, aspartic acid, glycine, leucine and potassium, but deficient in sulphur-containing amino acids. Dehusked tamarind seeds have been found to be a rich source of pectin, the jelly-forming constituent of many fruits, vegetables, seeds, etc. (Kumar, 1997). According to him proper utilization, can give an impetus to the jam and jelly industry which until now was dependent upon the imported jelly powder, and can also lead to the development of various other industries which use pectin as one of its raw materials. Methods of isolation and purification of the pectin have been described and its possible commercial uses indicated (Kumar, 1997).

25.3.4 Kernel powder

The powder, commercially known as tamarind kernel powder (TKP), is found to be extensively used as a sizing material in the textile industry as well as in the food industry (Rao and Subramanian, 1984; Bal and Mukherjee, 1994; Patil and Nadagouder, 1997). These analysts attribute the sizing properties of TKP to the presence of a polysaccharide (called jellose) to the extent of 6%. Other reported constituents are proteins, fibre, fat and inorganic salts and some free sugars and tannins. The jellose is also much used in confectionery, especially in the United States, and some European countries. Its use has been recommended in preparing jujubes, as a stabilizer in ice creams and mayonnaise (Patil and Nadagouder, 1997). Use of white TKP in three food products, jelly, fortified bread and biscuit was also detailed by Bhattacharya (1997), Bhattacharya *et al*. (1991, 1994b). It can be used in cosmetics, and in pharmaceutical and insecticidal preparation. It can also be used as an adhesive in bookbinding, cardboard manufacture and plywood industry, and in sizing and weighing compositions in the leather industry (Daw *et al.*, 1994; Patil and Nadagouder, 1997; Prabhanzan and Ali, 1995). The fatty oil from the kernels resembles peanut oil and is reported to be useful in the preparation of paints and varnishes and for burning lamps which can be extracted by solvent extraction (Pitka *et al.*, 1977; Reddy *et al.*, 1979; Patil and Nadagouder, 1997).

25.3.5 Seed testa

The testa is reported to contain 40% water solubles, 80% of which is a mixture of tannin and colouring matter (FRI, 1955). In the production of TKP or the jellose, large quantities of testa are left as a residual by-product. The use of testa in dyeing and tanning has been suggested. Several authors (Rao and Srivastava, 1974; Glicksman, 1986; Tsuda *et al.*, 1994, 1995; Sankaracharya, 1998) have suggested that seed coat, a by-product of tamarind gum industries can be used as a safe and low-cost antioxidant for increasing the shelf-life of foods by preventing lipid peroxidation. Studies have been carried out on the utilization of spent (detanned) tamarind seed testa as a substrate to grow *Pleurotus florida*, in order to convert organic wastes into biofertilizer and also to assess the

suitability of this testa as a substrate along with spent wattle. The yield of mushroom was 17% when wattle-tamarind seed testa was used. The spent material after harvesting the mushroom degraded easily in the soil indicating its suitability as organic manure (Madhulatha and Pitchai, 1997).

25.3.6 Minor uses

The tender leaves, flowers and the young seedlings are eaten as a vegetable. The analysis of tender leaves gave: moisture 70.5%; protein 5.8%; fat 2.1%; fibre 1.9%; other carbohydrates 18.2% and minerals 1.5%. The mineral and vitamin constituents (in mg/100 g) were as follows: calcium, 101; magnesium, 71; phosphorus, 140; iron, 5.2; copper, 2.09; chlorine, 94; and sulphur, 63; thiamine, 0.24; riboflavia, 0.17; niacin, 4.1; and vitamin C (Anon., 1976; Karuppaiah *et al.*, 1997). Young leaves of *T. indica* yielded 1.16 lipids (dry wt.) with chloroform-methanol and differentiated the neutral lipids, glycolipids and phospholipids (Sridhar and Lakshminarayana, 1993).

The leaves are eaten by goats and cattle. The flowers are considered to be a good source of honey (Ramanujam and Kalpana, 1992) which is rich golden in colour, but has slight acidity peculiar to its flowers. The tree also yields a valuable timber and the wood is used mostly for agricultural implements, tool-handles, wheels, mallets, rice pounders, and oil-mills and for turnery.

25.4 Functional properties

Medicinal values have been claimed for various preparations from the fruit, leaves, flowers, bark such as the antiscorbutic properties of the pulp, laxative action of the fruit juice and diuretic properties of leaf sap (Ghosh, 1987; Lakshmanan and Narayanan, 1990; Lewis *et al.*, 1970; Mustapha *et al.*, 1996; Rajan *et al.*, 1989; Rao, 1995; Sano *et al.*, 1996). An infusion of the leaves is said to be cooling and useful in bilious fever. A poultice of the fresh leaves is applied to swellings and boils, and for relieving pain, and that of the flowers in inflammatory infections of the conjunctiva. The bark is astringent and is given in diarrhoea; in lotions and poultices, it is also applied to sores and boils. In some countries, the bark is reported to be prescribed in asthma, amenorrhoea, and as a tonic and febrifuge (Anon., 1976).

The treatment of salted dried fish by TKP was found to be the best in preserving the quality of salted fish (Shetty *et al.*, 1996). While investigating the nutritive value of kernel proteins Sano *et al*. (1996) and Patil and Nadagouder (1997) remarked that it is comparable to that of cereal proteins based on their observations that replacement of 25% or less of rice by this kernel powder produced a significant improvement in the overall nutritive value of rice diet.

25.5 Quality issues

Tamarind has many problems associated with quality parameters due to high moisture level and seed, fibre and rind contents. Tamarind is reported to be adulterated with foreign matter which are both organic and inorganic in nature. They are considered to be due to poor post-harvest management practices including processing (Rao and George, 1996; George and Rao, 1997). Directorate of Marketing and Inspection and Bureau of

Table 25.1 Agmark specifications (%/wt max) – tamarind seedless

Character/grade	Special	A	B	C
Moisture	15	17	20	20
Seed content	5	10	15	20
Foreign matter (organic)	4	6	8	10
Foreign matter (inorganic)	1	1.5	2	2

Table 25.2 Agmark specifications (%/wt max) – tamarind dry

Character/grade	Special	A	B
Seed content	35	40	45
Fibres	6	8	10
Rind	3	4	6
Insect damage	2	3	5
Moisture	15	20	25

Table 25.3 Agmark specifications (%/wt max.) – tamarind seed

Character/grade	Special	A
Extraneous matter	1	2
Damaged and discoloured	2	5
Wt/lit	900	800
Moisture	9	10

Indian Standards have prescribed quality specifications for seedless tamarind (Table 25.1), dry tamarind (Table 25.2) and tamarind seed (Table 25.3) (Anon, 1996c). The Indian Standard specifications are available for tamarind juice concentrate (IS:5955, 1993), pulp (IS:6364, 1993), for kernel oil (IS:189, 1977), IS: 511, 1962 for kernel powder and IS 9004, 1978 for seed testa.

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26

Turmeric

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26.1 Introduction

Turmeric of commerce is the dried rhizome of the plant *Curcuma domestica* Val. syn. *C. longa* L. Turmeric is used in curry powder, chicken bouillon, sauces, gravies, dry seasonings, backing mixes, processed cheese pickles, relishes, breading soups, beverages, and confections (Peter, 1999) in addition to its use in medicine, religious functions and as biopesticide.

The genus *Curcuma* originated in the Indo-Malayan region (Purseglove, 1968). Considerable species diversity of *Curcuma* occurs in this region. However, about 40 species of the genus including *C. longa* are indigenous to India indicating the Indian origin (Velayudhan *et al.*, 1999). The antiquity of turmeric dates back to the Assyrians of 600 BC. Ethnobotanical evidence indicates that the use of turmeric has been in India since very ancient days. It is believed that the crop spread out from India to distant Asian countries under the influence of the Hindu religion. According to Marco Polo (1280) the spread of turmeric to China took place in AD 700 (Ridley, 1912). Burkill (1966) believed that the crop spread to West Africa in the thirteenth and to East Africa in the seventeenth centuries, respectively. It was introduced to Jamaica in 1783 (Velayudhan *et al.*, 1999). Though turmeric is now grown in India, Pakistan, Malaysia, Myanmar, Vietnam, Thailand, Philippines, Japan, China, Korea, Sri Lanka, Nepal, South Pacific Islands, East and West Africa, Malagasi, Caribbean islands, and Central America, India is the major producer and exporter of turmeric at present.

The genus *Curcuma* belongs to the family *Zingiberaceae* and contains 49 genera and 1400 species. In addition to *Curcuma longa*, *C. zedoaria* Rosc. and *C. xanthorrhiza* Roxb. are also minor sources of curcumin colour. Velayudhan *et al.* (1999) recognized six taxonomic varieties within *C. longa* based on numerical taxonomic analysis, namely *C. longa* var. *typica*, *C. longa* var. *atypica, C. longa* var. *camphora, C. longa* var. *spiralifolia, C. longa* var. *musacifolia* and *C. longa* var. *platifolia*. Most of the *C. longa* found in India belong to *C. longa* var. *typica* or *atypica.*

Turmeric is an erect perennial herb, grown as an annual crop. The above ground morphology of the plant is mainly represented by an erect pseudostem bearing leaves and inflorescence. There may be 2–3 pseudostems (tillers) per plant. The height of the

pseudostem varies from 90–100 cm depending on the variety. Leaf number ranges from 7–12. In fact, it is the leaf sheath which forms the pseudostem. The leaf sheath is usually green in colour. Lamina may be lanceolate or elliptic in shape, thin with acuminate tip. The colour of lamina is usually green above and pale green below, with a length of about 30–40 cm and width 8–12 cm. Inflorescence is a cylindrical, fleshy, central spike of 10–15 cm length, arising through the pseudostem. Flowers are subtended by bracts in the spike. The bracts are adnate for less than half of their length and are elliptic, lanceolate and acute. The upper bracts are white in colour while the lower bracts are green. One to four flowers are borne in the axil of the bract, opening once at a time. About 30 flowers are produced in a spike (Nazeem and Rema Menon, 1994). The calyx is short, usually toothed and split nearly halfway down on one side. The corolla is tubular, thin and whitish with a yellow tip. Usually the upper most and lower most bracts will be sterile. Seed set is observed in turmeric and seeds are viable. Seeds are produced in capsules and there will be from one to numerous sunken capsules in an inflorescence depending on the flowers fertilized.

At the base of the pseudostem, below the ground, rhizomes are formed consisting of mother rhizome(s), primary, secondary and even tertiary fingers, the whole forming a compact clump. Rhizomes grow symbodically and are of orange brown, pale yellow or reddish yellow colour.

C. longa is considered to be a triploid with a somatic chromosome number of 63 (2n = 3x = 63).

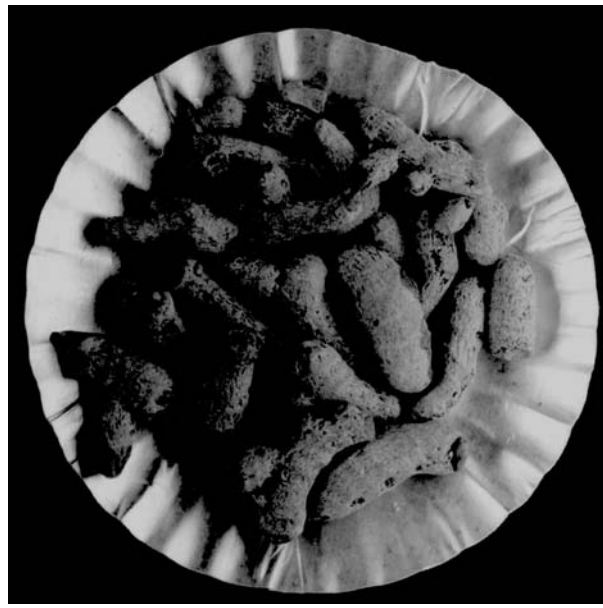
26.2 Production

India is the major producer and exporter of turmeric in the world. In India turmeric is grown over 1.34 ha with an annual production of 5.43 lakh tonnes. India exported 23 000 t of turmeric during 1996–97 to 67 countries (Peter, 1999). Turmeric is exported as turmeric dry, turmeric fresh, turmeric powder, turmeric oleoresin and turmeric oil. The major turmeric importing countries from India are Iran, Japan, South Africa, Singapore, Sri Lanka, USA, UAE, Malaysia, Germany and Bangladesh. Export of turmeric by item from India during 1994–96 is given in Table 26.1.

There are about 60 turmeric cultivars (land varieties) available in the country. Some of the important local cultivars are 'Duggirala', 'Tekurpet', 'Sugandham' 'Amalapuram', 'Lakadong', 'Alleppey', 'Rajapuri', 'Mydukur', 'Wynad local', etc. Cultivars like 'Alleppey', 'Wynad local', 'Lakadong', 'Edapalayam', 'Thodupuzha', etc., are rich in curcumin content (>7%). In addition to these land varieties, there are about 17 improved varieties in India. The important improved turmeric varieties are 'Prabha', 'Prathibha' (Fig. 26.1), 'Sudarsana', 'Suguna', 'Co-1', 'Sugandham', 'BSR 1', etc. (Sasikumar *et al.,* 1996). Maturity of these varieties is 7–9 months. The yield (fresh) of the improved varieties is 20–40 t/ha.

Table 26.1 Export of turmeric from India during 1994–96

Item	1994–95 Quantity (t)	1995–96 Quantity (t)
Turmeric dry	16,727.9	19,189.5
Turmeric fresh bulk	5964.1	800.9
Turmeric powder	6093.7	7385.9
Turmeric oil	0.3	0.1
Turmeric oleoresin	159.0	149.1



26.1 Prathibha

26.3 Post-harvest processing

Harvested turmeric is washed well to remove the adhering soil; roots removed, the fingers and mothers are separated. Mother and finger rhizomes are boiled separately for about 40–60 minutes under slightly alkaline condition (100 g of sodium bicarbonate or sodium carbonate in 100 l of water) in copper, galvanized iron or earthen vessels and sun dried on bamboo mat or clean drying floor for 10–15 days so as to bring down the moisture content to 10%.

Another method of curing is by taking cleaned mother and finger rhizomes (approx. 50 kg) separately in perforated trough of convenient size made of GI or MS sheet with extended parallel handle. The trough containing the fingers are immersed in water using a paddle. The alkaline solution is then poured into the pan so as to immerse the rhizome, which are then boiled until they become soft and dried. The dry recovery of cured turmeric varies between 15–30% depending on variety, location and cultural practices.

Dried turmeric is subjected to polishing either manually or mechanically in power operated drums (Purseglove *et al.*, 1981). A weight loss of about 5–8% is expected due to full polishing. Polished rhizomes are made attractive by artificially colouring them with turmeric powder. During polishing itself turmeric is added to the drum either as powder or as emulsion.

Rama Rao *et al.* (1975) described an indigenous method of storing turmeric. The cured product is stored in suitable pits dug on a raised site. The bottom and sides of the pits are lined thickly with dried grass or similar material. After filling up the pits with the cured turmeric they are covered with mat or grass and finally with earth. The produce can be stored for one year like this. At Sangli, India, farmers usually store turmeric like this in pits dug in the field. Dealers usually store the cured turmeric in fresh jute bags or in sound, clean, dry, heat-sealed polythene bags in dry, cool, warehouses (Purseglove *et al.*, 1981). After harvest, fresh turmeric is kept in gunny bags or baskets or heaped open in well-ventilated sheds.

Turmeric is available as whole, ground, oleoresin and oil. Turmeric is used mainly as fine ground turmeric in cooking in the West while those in the growing countries buy turmeric mostly in whole or split form. Importing countries in the West buy ground turmeric, turmeric oleoresin and oil.

26.3.1 Ground turmeric

A sophisticated grinding process is not needed for ground turmeric, since there would not be much loss of quality while grinding turmeric. Usually clean, dry, stone-hard fingers are powdered through the use of hammer mills followed by disc-type attrition mills to obtain 60–80 mesh powder. Accessory equipment for pre-cleaning includes an aspiration system (which removes the light extraneous matter), destoners and magnetic separators for fine iron contamination, vacuum fumigators, and the noise reducing fixtures, dust collection systems, mechanical or closed circuit pneumatic conveying system, blending and automatic packaging system, now employed by most big spice grinders for optimizing the output and for assuring hygienic and flavour quality. The smaller spice manufacturers in the West and Asia use simple cleaning and grinding equipment and partly mechanized packaging systems (Govindarajan, 1980).

Turmeric powder is packed in bulk in containers such as fibre hard drums, multi-wall bags and tin containers suitably lined or coated to prevent moisture absorption, loss of flavour and colour. For the retail trade the unit packages are in flexible packagings such as low and high density polyethylene, polyvinyl chloride, glassine or in glass packages.

Storage studies conducted on turmeric powder using different packaging materials have shown that aluminium foil laminate or double pouch of glassine or low density polyethylene offered good protection for the stored product for about six months without loss of quality and colour (Balasubramanian *et al.*, 1979).

26.3.2 Turmeric oleoresin

Turmeric oleoresin is being used increasingly by the processed food industries in the West to impart colour and aroma. Oleoresin is a mixture of compounds, namely curcumin, volatile oil and other active ingredients, non-volatile fatty and resinous material extractable by solvents, used singly, in sequence or in combination. Turmeric oleoresin is orange-red in colour and consists of an upper oily layer and a lower crystalline layer (Krishnamurthy *et al.*, 1976). For commercial use, it is usually mixed with a non-volatile edible solvent such as vegetable oil, propylene glycol or polyoxy ethylene sorbitan fatty acid esters in order to disperse the extracted material and to render it free flowing and 'soluble' (Purseglove *et al.*, 1981).

Turmeric oleoresin is obtained by solvent extraction of ground spice. Acetone is a good solvent for oleoresin extraction. Soxhlet apparatus or cold percolation is used for extraction. Curcumin, the principal colouring matter forms about one third of a good quality oleoresin. Yield of oleoresin varies from 7–15% depending on varieties. Govindarajan (1980) has given the detailed steps for industrial extraction of turmeric oleoresin.

26.3.3 Turmeric oil

Turmeric contains 3–5% volatile oil, which is obtained by steam distillation of turmeric powder, for about 8–10 h. Turmeric oil is pale yellow in colour with peppery and aromatic odour. The oil contains about 60% turmeron, 25% zingiberene and small quantities of d-α-phellandrene, d-sabinene, cineole and forneol.

26.3.4 Curry powder

Turmeric powder is the major component (about 40–50%) of curry powder. Curry powder is a spice mixture used for seasoning dishes containing vegetables, meat, fish, eggs or vegetable plus meat or fish (i.e. curry) in the orient. In the West also curry powder is used for seasoning dishes. India has been the principal exporter of curry powder to many countries like the UK, Australia, Fiji, etc.

Turmeric powder provides colour and background aroma to the curry powder. Govindarajan (1980) has given typical curry powder composition, quality standards, packaging details, etc.

26.4 Quality specifications

Cured turmeric is sorted as fingers, round, split or non-specified and marketed under its varietal name, which is usually based on the place of production such as 'Alleppey', 'Erode', 'Duggirala', 'Nizamabad', 'Rajapuri', 'Cuddappah', etc., from India. The Indian 'Agmark', standards include separate gradings for different varieties. 'Special', 'good' and 'fair' are some of the grade specifications. Govindarajan (1980) has given the specification for turmeric (whole and ground).

1. Turmeric whole is the primary (bulbs, rounds) and secondary (fingers) rhizomes, harvested at full maturity, cured, dried to about 10% moisture level, polished and either coloured or not coloured.
2. The cured rhizomes, cleaned and dried, are ground to powder without any added matter.
3. Whole or powdered turmeric should have the characteristic fresh aroma and taste of turmeric and be free from foreign aroma such as mustiness. It must also be free from living insects, moulds; practically free from dead insects, insect fragments and rodent contamination visible to the naked eye or specified magnification.
4. Turmeric fingers should not be less than 15 mm in length, hard, smooth and the core colour should be lemon yellow or bright yellow with only admissible levels of small pieces and bulbs (Table 26.2).
5. Turmeric whole should not contain more than 2% by weight (lower limit for superior grade) extraneous matter. The admissible level of defective rhizome allowed in different varieties of turmeric is given in Table 26.2.
6. The limits for chemical characteristics specified for turmeric powder are presented in Table 26.3.

American Spice Trade Association (ASTA) cleanliness specification effective from 21 May 1997 for turmeric allows only a maximum of three dead whole insects; 5 mg/1b mammalian or other excreta, 3% by wt. mould, 2.5% by wt. insect defiled or infested material and 0.5% by wt. extraneous foreign matter in turmeric (Sivadasan, 1998).

Whole, dried or fresh turmeric is usually free from adulteration. However, turmeric powder is adulterated with foreign starch (tapioca, arrowroot, cereal floor), husks, coal tar colours, lead chromate, etc. Adulterated turmeric powder will have low curcumin content. Depending upon the adulterant used, the curcumin content of the samples vary from 0.37–2.07% (Balasubramanian *et al.*, 1979). Gas chromatographic methods are available to detect volatile oil of other *Curcuma* sp. used for admixing the turmeric powder. Similarly, specific tests are now available to detect each of the above adulterants in ground turmeric (Govindarajan, 1980).

Table 26.2 Indian specification for turmeric grade

Grade	Pieces (max. wt. %.)	Foreign matter (max. wt. %.)	Defectives (max. wt. %.)	Bulks (max. wt. %.)	Characteristics
Fingers (general)					Finger-like shape, breaks with a metallic twang; well set and close grained; perfectly dry, free from weevil damage, over boiling, etc.
Special	2.0	1.0	0.5	2.0	
Good	3.0	1.5	1.0	3.0	
Fair	5.0	2.0	1.5	5.0	
Fingers (Alleppey)					
Good	5.0	1.0	3.0	4.0	As above
Fair	7.0	1.5	5.0	5.0	
Fingers (Rajapuri)					
Special	3.0	1.0	3.0	2.0	As above, admixture of other turmeric varieties are allowed at a maximum of 2.5 and 10% in 3 grades, respectively.
Good	5.0	1.5	5.0	3.0	
Fair	7.0	2.0	7.0	5.0	
Bulbs (rounds)					
Special	–	1.0	1.0	–	Be well developed, smooth round and free from rootlets The 'Rajapuri' type has higher allowance of 3.0, 5.0 and 7.0% defectives in 3 grades, respectively.
Good	–	1.5	3.0	–	
Fair	–	2.0	5.0	–	

Source: Govindarajan (1980).

26.5 Chemical structure

Turmeric is valued mainly for its principal colouring pigment, curcumin, which imparts the yellow colour to turmeric, besides other nutritive constituents like potassium (Peter, 1999) (Table 26.4).

The main colouring constituent of turmeric and other yellow *Curcuma* species is curcumin, having a molecular formula of $C_{21}H_2O\ O_6$. In fact, besides curcumin there are a few other related pigments which imparts the yellow colour, all together called curcuminoids (Verghese, 1999). Curcumin [1,7-*bis* (4-hydroxy-3-methoxy-phenyl)-1,6-heptadiene-3,5-dione]; demethoxy curcumin [4-hydroxy-cinnamoyl (4-hydroxy-3-methoxycinnamoyl) methane and *bis*-demethoxy curcumin [bis-(4-hydroxy cinnamoyl methane] together make the colouring pigment in the turmeric rhizomes (see Fig. 26.2).

The curcumin content in different turmeric varieties varies from 2–8% (spectrophotometric estimation). However, Verghese (1999) reported the total colour in eight *C. longa* varieties ranging from only 2.3–3.9%, by HPLC analysis. 'Alleppey' type recorded maximum colour. The distribution of the curcuminoids is also reported to vary with different samples (Table 26.5) (Verghese, 1999).

In the pure form curcuminoids separate as an orange yellow crystalline powder, insoluble in water, slightly soluble in ether, soluble in alcohol and in glacial acetic acid. Verghese (1999) is of the opinion that the melting point of curcumin is an unworthy

Table 26.3 Analytical specification for turmeric (whole and powder)

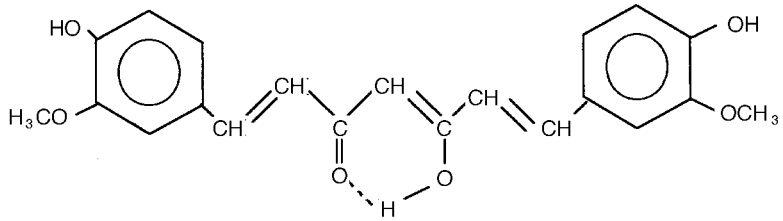
Sample	Moisture max. (% wt.)	Ash		Starch max. (% wt)	Crude fibre max. (% wt.)	Vol. oil max. (% wt.)	Colour as curcumin min. (% wt.)	Lead max. ppm	Chromate test
		Total max. (% wt.)	Acid insol. max. (% wt.)						
Whole BP	8–10	6–9	–	–	4–6	2–5	–	–	–
US	9	7	0.5	–	6	4	5	–	–
DDR	–	7	–	–	–	2.6	3–4	–	–
Powder India	10	7	1.5	60.0	–	–	–	1.5	Negative
WHO	10	7	1.5	–	–	–	–	3	Negative

Note: The chromate test is negative if there is no violet colour developed when dilute acid soluble ash from 2 g of sample (4–5 ml) is reacted with 1 ml of 0.2% alcoholic solution of diphenyl carbazide.
Source: Govindarajan (1980).

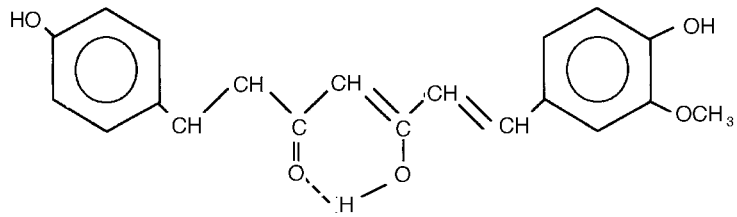
Table 26.4 Nutritional composition of turmeric

Constituent	Quantity per 100 g
Water (g)	6.0
Food energy (Kcal)	390
Protein (g)	8.5
Fat (g)	8.9
Carbohydrate (g)	69.9
Ash (g)	6.8
Calcium (g)	0.2
Phosphorous (mg)	260
Sodium (mg)	30
Potassium (mg)	2000
Iron (g)	47.5
Thiamine (mg)	0.09
Riboflavin (mg)	0.19
Niacin (mg)	4.8
Ascorbic acid (mg)	50

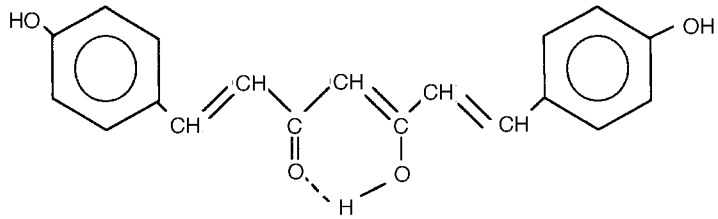
Source: Peter (1999).



(a) Curcumin



(b) Demethoxy curcumin



(c) *bis* -Demethoxy curcumin

Fig. 26.2 Structures of (a) curcumin, (b) demethoxy curcumin and (c) *bis*-demethoxy curcumin.

Table 26.5 Concentration of curcuminoids in typical curcumin samples by HPLC analysis

Sample	Curcumin (%)	Demethoxy curcumin (%)	*bis*-demethoxy curcumin (%)	Total (%)
1. Curcumin puriss (Fluka)	53.5	17.2	9.6	80.3
2. Curcumin crys. natural (Koch-light)	80.8	7.1	1.0	89.9
3. Pure curcumin (Chr. Harsen)	64.9	11.3	6.4	82.6
4. Curcumin/(Syndiferuloyl methane (ICN) (1)	79.6	12.2	1.6	93.4
5. Curcumin (ICN)	58.3	16.6	7.0	81.9
6. Curcumin (Biomol)	66.3	15.3	4.0	85.6
7. Synthite 1	71.0	23.2	2.8	97.0
8. Synthite 2	68.6	23.0	3.0	94.6

Source: Verghese (1999).

quality parameter and need not be mentioned in any specifications, as many different melting points are reported by many workers for curcuminoids!

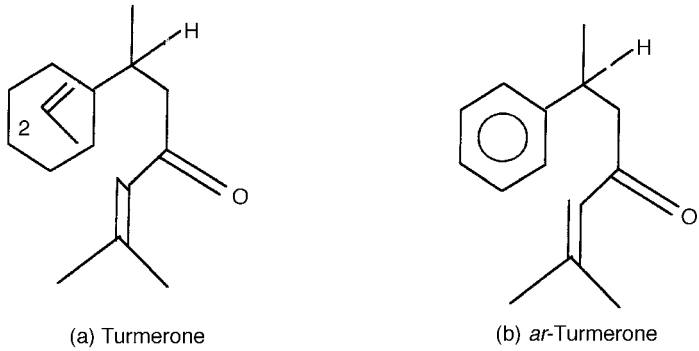
Curcumin exhibits strong absorption between 419 and 430 nm in organic solvents and on this property revolves the spectrophotometric methods of the American Spice Trade Association (1968) and Essential Oil Association (EOA) (1965), though now the HPLC method is available (Tonnesen and Karlson, 1983). The EOA stresses the fact that 'turmeric extracts are evaluated strictly in colour' and this is best expressed in terms of colour value (cv), which is equivalent to ten times the specific extinction coefficient in ethanol at 422 nm (c.f. Verghese, 1999). Verghese (1999) further reported that the specific extinction coefficient in ethanol of curcumin at 420–430 nm varies between 1528 and 1586, of demethoxy curcumin at 420–430 nm between 1513 and 1580, and of *bis*-demethoxy curcumin at 419–430 nm between 1565 and 1682. By repeated crystallization from ethanol, the dye yielded specific extinction coefficient 1596 at 425 nm in ethanol (c.f. Verghese 1999). Coupling this observation and the values already reported in the literature, specific extinction coefficient 1600 was recommended as a reasonable yardstick for assaying curcumin and this fits the HPLC data excellently (Verghese, 1999).

However, for most routine, quality control work, it is sufficient to measure the extinction of an alcohol extract at the absorption maximum at 420–455 nm, taking the precautions of using neutral alcohol and avoiding exposure to direct sunlight, and calculate the curcumin content by using the molecular absorption value (Govindarajan, 1980).

Turmeric oil has a major role in the aroma and flavour of turmeric though the oil as such is not used. Turmeric oil is comprised of oxygenated sesquiterpenes which are accompanied by smaller quantities of sesquiterpene hydrocarbons, monoterpene hydrocarbons and oxygenated monoterpenes (Purseglove *et al.*, 1981). Among the various constituents of the oil, sesquiterpenes, *ar*-turmerone and turmerone comprise 50 per cent of the oil (see Fig. 26.3) (Purseglove *et al.*, 1981).

26.6 Use in the food industry

Turmeric powder is used in mustard paste and curry powder as both colour and aroma are important in these products. Turmeric oleoresin is used mainly in the brine pickles



(a) Turmerone (b) *ar*-Turmerone

Fig. 26.3 (a) Turmerone, (b) *ar*-Turmerone.

(Eiserle, 1966; Cripps, 1967) and to some extent in mayonnaise and relish formulations; in non-alcoholic beverages such as orangeades and lemonades; gelatins; in breading of frozen fish sticks; potato croquettes; butter and cheese in the form of powder or granules for garnishing and even in ice creams (Perotti, 1975). In all these cases, its function is predominantly to colour the product and it merely replaces the synthetic colours such as tartrazine, formerly used (Govindarajan, 1980).

In Asian countries whole, dry or fresh turmeric, ground or turmeric powder with other spices like chillies, coriander, pepper, cumin, etc., are used for making vegetable and meat dishes and soup-like dishes. Turmeric powder mixed with seasame, coconut or groundnut oil is used for pickling mango, lime, gooseberry, garlic, etc. (Govindarajan, 1980).

The colours in the Food Regulation Act came into force in UK in 1996. Part III, Schedule 5 of this Regulation specifies the limits for curcumin in various food items (Table 26.6) (Henry, 1998). Curcumin is included in the list of colours with a restricted use because of the fact that it has been allocated only a temporary, low ADI value (acceptable daily intake). The ADI value indicates the amount of a food additive that can be taken daily in the diet without risk, expressed as mg/kg/bodyweight (Henry, 1998). The Joint Expert Committee on Food Additives (JECFA) has allotted curcumin a temporary ADI value of 0–1.0 mg/kg/bodyweight/day. Curcumin is specifically permitted as a colour in the EU though many countries simply list it without a specification for its colour strength.

Pure 95% curcumin, as it is usually obtained, is not an ideal product for direct use by the food industry since it is insoluble in water and has poor solubility in other solvents. Hence in many countries curcumin is dissolved in a mixture of food grade solvent and permitted emulsifier such as Polysorbate 80 for converting into a convenient application form. In this form the product contains about 10% curcumin.

Curcumin gives a bright yellow colour even at low doses. The usual dose level of curcumin is in the range of 5–200 ppm. Numerous blends are available commercially to suit the colour of the product (Henry, 1998). Vanilla ice cream for example is coloured with a combination of curcumin (200 ppm) and norbixin (12 ppm). Similarly in yoghurt 5 ppm curcumin will give an acceptable colour. For cakes and biscuits the required colour is achieved using a blend of curcumin (10–15 ppm) and annatto (10 ppm).

Turmeric oleoresins although permitted universally as a spice oleoresin, are not a permitted colour in EU (Henry, 1998). Turmeric powder, extracts and curcumin exhibit antioxidant property as observed by the induction period and oxygen absorption of coconut, groundnut, safflower, sesame, mustard, cotton seed oil and ghee at 95C to 220C for period up to 144 h. In foods, the antioxidant property of turmeric was effective in preventing peroxide developments (Khanna, 1999).

Table 26.6 Limits specified for curcumin in various food items ('Colours in Food Regulation Act 1995' Schedule 5, Part III)

Food	Maximum level
Non-alcoholic flavoured drinks	100 mg/l
Candied fruits and vegetables, mostarda di frutta	200 mg/kg
Preserves of red fruits	200 mg/kg
Confectionery	300 mg/kg
Decorations and coatings	500 mg/kg
Fine bakery wares (e.g. viennoiseric, biscuits, cakes and wafers)	200 mg/kg
Edible ices	150 mg/kg
Flavoured processed cheese	100 mg/kg
Desserts including flavoured milk products	150 mg/kg
Sauces, seasonings (for example, curry powder, tandoori pickles, relishes, chutney and piccalilli)	500 mg/kg
Mustard	300 mg/kg
Fish paste and crustacean paste	100 mg/kg
Pre-cooked crustaceans	250 mg/kg
Salmon substitutes	500 mg/kg
Surimi	500 mg/kg
Fish roe	300 mg/kg
Smoked fish	100 mg/kg
'Snacks': dry, savory potato, cereal or starch-based snack products: extruded or expanded savoury snack products	200 mg/kg
Edible cheese rind and edible casings	quantum satis
Complete formulae for weight control intended to replace total daily food intake or an individual meal	50 mg/kg
Complete formulae and nutritional supplements for use under medical supervision	50 mg/kg
Liquid food supplements/dietary integrators	100 mg/l
Solid food supplements/dietary integrators	300 mg/kg
Soups	50 mg/kg
Meat and fish analogues based on vegetable proteins	100 mg/kg
Spirituous beverages (including products less than 15% alcohol by volume), except any mentioned in Schedule 2 or 3	200 mg/l
Aromatized wines, aromatized wine-based drinks and aromatized wine-product cocktails as mentioned in Regulation (EEC) No. 1601/91, except any mentioned in Schedule 2 or 3	200 mg/l
Fruit wines (still or sparkling), cider (except cidre bouche) and perry aromatized fruit wines, cider and perry	200 mg/l

Source: Henry (1998).

The fate of curcumin *in vivo* is yet to be understood thoroughly. Studies by oral administration of curcumin to rats indicated that curcumin is metabolized to a certain extent in the liver and that curcumin and its metabolites are excreted via bile and faeces (Tonnesen, 1986).

26.7 Functional properties

Many reviews are available on the medicinal uses of turmeric (Kirtikar and Basu, 1948; Anon., 1950; Srimal, 1993; Verghese, 1999; Khanna, 1999). In the traditional systems of medicine turmeric is used against many ailments.

The biological activity of turmeric is as anti-inflammatory, hypocholestremic, choleratic, antimicrobial, antirheumatic, antibacterial, antiviral, cytotoxic, spasmolytic, hypersensitive, antidiabetic and antihepato toxic (Govindarajan, 1980; Tonnessen, 1986; Velayudhan *et al.*, 1999). Turmeric is also credited with anticancerous properties (Kuttan *et al.*, 1985, Rao *et al.*, 1995).

Curcuminoids, turmeric oil, total extracts are all credited with medicinal properties (Khanna, 1999). However, the biological activity of the components of these constituents differ considerably (Verghese, 1999). It is reported that the proportions of curcuminoids play a considerable role in optimum bioprotective activity of turmeric. The concept of 'Curcumin C3 complex' stamped with specific concentration limit of the individual curcuminoid is an off shoot of this finding (Verghese, 1999).

The dried rhizome of turmeric is used widely as a spice, as a colouring agent and as a folk medicine. The yellow pigment curcumin and demethoxyylated curcumins found in both turmeric and ginger are known to possess potent antioxidant activity (Kikuzaki *et al.*, 1994; Kikuzaki and Nakatani 1993). Curcumin suppressed the oxidation of methyl linoleate in organic homogeneous solution and aqueous emulsions, soybean phosphatidylcholine liposomal membranes and rat liver homoganate induced by free radicals (Noguchi *et al.*, 1994). A mechanism for the dimer production is proposed and its relation to curcumin's antioxidant activity is discussed in Masuda *et al*. (1999). The results indicated that the dimer is a radical-terminated product formed during the initial stage of the process.

In vitro and *in vivo* studies have established the effectiveness of curcumin, volatile oil or total extracts of turmeric against many organisms such as *Micrococcus pyogenous* var. *aureus, Staphylococcus* sp., *Paramacium caudatum, Trichophyton gypseum, Mycobacterium tuberculosis, Salmonella typhi, Vibrio cholerae, Cornybacterium diphtheria, Aspergillus niger*, etc. (Khanna, 1999).

Aqueous extract, fresh juice and essential oil of turmeric are also credited with biopesticidal properties (Kapoor, 1998; Saju *et al.,* 1998; Bora and Jaya Samuel, 1999). *In vitro* and *in vivo* studies have established the efficacy of turmeric constituents against various plant pathogens such as *Ralstonia solanacearum*, *Xanthomonas oryzae* pv. *oryzae, Helminthosporium sacchari*, *Colletotrichum gloesporoides, Rhizoctonia solani*, etc. Turmeric oil is also effective as a mosquito repellant, housefly deterrent and in aphid vector control (Khanna, 1999; Saju *et al.*, 1998).

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