1 Introduction

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Spices and herbs have played a dramatic role in civilization and in the history of nations. The delightful flavour and pungency of spices make them indispensable in the preparation of palatable dishes. In addition, they are reputed to possess several medicinal and pharmacological properties and hence find position in the preparation of a number of medicines.

1.1. Historical Perspective

Many maritime routes were developed to India and China with an ultimate desire to develop a spice route. In the late 13th century, Marco Polo's exploration of Asia established Venice as the most important trade port. Venice remained prosperous until about 1498. The Portuguese explorer, Vasco de Gama, sailed around Africa's Cape of Good Hope to reach Calicut, India. He returned with pepper, cinnamon, ginger and jewels, and also deals for the Portuguese to continue trade with India.

Rosengarten (1969) has presented a very interesting history of spices. In 1492, Christopher Columbus arrived in America while searching for a direct western route to the Spice Islands. Though he did not find the Spice Islands, Columbus brought allspice, vanilla and red peppers from the West Indies back to his Spanish supporters. Conflict developed over who would dominate this prosperous trade. Wars over the Indonesian Spice Islands broke out between the expanding European nations and continued for about 200 years, between the 15th and 17th centuries.

In 1780, the Dutch and English fought a war over the spice trade and the Dutch lost all spice trading centres. The Americans began their entry into the world spice race in 1672 (ASTA, 1960).

From the beginning of history, the strongest nations have controlled the spice trade. The same is true today; the USA is now the world's major spice buyer, followed by Germany, Japan and France.

In short, the trade in spices, usually carried out along the many historic spice routes, has been one of the most important commercial activities throughout ancient and modern times. The importance placed on spices is reflected by economic developments that began early in many ancient civilizations, where spices found applications in food preservation, cooking and traditional medicine.

Asia still grows most of the spices that once ruled the trade, including cinnamon, pepper, nutmeg, clove and ginger. However, more and more spices are being planted in the Western hemisphere, along with a wide variety of herbs and aromatic seeds. Brazil is a major supplier of pepper. Guatemala is a leading producer of cardamom. Grenada grows nutmeg and ginger, and allspice is grown in Jamaica. Nicaragua, El Salvador and the USA grow sesame seed. Europe and the USA produce many herbs and Canada grows several aromatic seeds.

1.2. Global Spice Trade

The major markets in the global spice trade are the USA, the European Union, Japan, Singapore, Saudi Arabia and Malaysia. The principal supplying countries are China, India, Madagascar, Indonesia, Vietnam, Brazil, Spain, Guatemala and Sri Lanka. During the review period from 2000 to 2004, the value of spice imports increased by an average of 1.9% per year and the volume increased by 5.9%. World trade in spices in 2004 consisted of 1.547 million t, valued at US$2.97 billion. An annual average rate of 7% was seen in the global import volume of spices in the period 2000–2002, whereas the import values decreased by 5% annually. This was attributed to the dramatic decrease in the value of whole pepper during 2000/01 by about 40% and a further 18% in 2002/03 (Table 1.1).

Higher market prices for major commodities such as paprika, vanilla, ginger, bay leaves and spice mixtures resulted in an upward value trend by 4.6% from 2003 to 2004, with a stabilized import volume. There was a growing trend towards the trade of processed spices, which fetched higher prices. The increasing demand for value-added processing of spices, such as capsicum and ginger, offers business opportunities for the food and extraction industries in international markets (International Trade Centre, 2006).

World import for black pepper achieved only minor increases in volume during 2000–2004. On average, 260,000 t of black pepper is imported yearly into the global market. While growth in volume trade rose marginally, import values for *whole pepper* declined steeply by 54% from US$854 million to US$394 million in that period, resulting in lower world prices for pepper. Vietnam, Indonesia, Brazil, Malaysia and India are the major producers and exporters of black pepper. With an export volume of 96,113 t, valued at US$136.6 million in 2004, Vietnam is the world's largest exporter in the black pepper trade.

In the case of ginger, Japan is the number one importer in the world. Japan's imports of ginger reached more than 100,000 t, valued at US$126 million, which accounted for 50% of the country's total spice imports in 2004. The principal supplier of quality ginger to the Japanese market is China, with exports exceeding 70,000 t, valued at US$93 million, followed by Thailand with 26,000 t.

Vanilla is the second most expensive spice after saffron because its production is very labour-intensive. The world market for vanilla is highly concentrated in the USA, France and Germany. In 2004, US imports of vanilla amounted to US$205 million, followed by France and Germany (US$44 million and US$36 million, respectively). These importing countries represent 72.5% of the world vanilla trade.

As an average, import values of nutmeg, mace and cardamom decreased by 7% annually, whereas volumes recorded a slight increase over 2000–2004. Imports of cardamom made up 60% and nutmeg and mace 40% of the total import value of US$204 million in 2004.

International trade in mixed spices (curcuma, turmeric and curry powder, laurel leaves, curry paste, dill and fenugreek seeds) grew by 5% and 11% in volume and value terms, respectively, in 2003/04. The main importing countries were the USA, Belgium, Germany, the Netherlands and the UK. India supplied 14% of the total import value of this spice category to the US and UK markets in 2004.

Table 1.2 shows the exports and market shares of the leading spice producing countries during 2000–2004. These major exporters account for a value share of more than 55% in the 2004 world import trade of spices. In terms of export competitiveness, China has emerged as the principal exporter. Its export share increased sharply in 2003/04 to 13.2%, up from 9.7%, surpassing India

Table 1.1. World imports of different spices.

	Quantity (thousand t)					Value (US$ million)				
Spice category	2000	2001	2002	2003	2004	2000	2001	2002	2003	2004
Pepper, whole	216.1	228.9	246.6	228.8	237.0	854.3	492.3	402.4	425.1	394.6
Pepper, crushed/ground	23.7	22.1	27.4	30.5	32.4	95.0	72.1	75.4	92.3	99.5
Total pepper	239.8	251.0	274.0	259.3	269.4	949.3	564.4	477.8	517.4	494.1
Capsicum	230.7	273.1	324.8	350.1	371.0	370.6	426.1	453.5	492.0	590.4
Vanilla	4.3	4.4	6.8	5.0	3.5	108.2	240.7	308.5	535.9	394.9
Cinnamon, whole	73.4	68.3	78.4	70.4	75.2	108.6	108.1	106.5	100.1	105.6
Cinnamon, crushed/ground	9.8	10.1	13.4	13.0	13.2	16.7	16.2	20.2	20.6	22.6
Total cinnamon	83.2	78.4	91.8	83.4	88.4	125.3	124.3	126.7	120.7	128.2
Cloves, whole and stems	50.3	53.1	29.5	50.3	43.9	148.2	148.2	124.1	101.2	115.9
Nutmeg, mace, cardamom	42.2	41.9	46.3	50.1	47.5	279.9	279.9	236.9	215.6	204.4
Spice seeds	201.2	186.4	207.0	213.8	220.3	207.8	207.8	207.0	201.3	207.5
Ginger (except preserved)	213.7	234.1	236.2	313.8	284.1	206.6	206.6	143.1	177.9	305.3
Thyme, saffron, bay leaves	15.3	17.9	18.3	20.1	20.6	77.9	77.9	80.0	95.9	106.9
Other spice mixtures	173.5	249.2	202.0	189.5	198.4	292.7	292.7	321.6	383.3	427.3
Total spice imports	1254.0	1389.6	1436.7	1535.4	1547.2	2766.5	2766.5	2479.2	2841.2	2973.9

Source: International Trade Centre (2006).

Table 1.2. Main spice-exporting countries by commodity; value and percentage share, 2004.

Spice category	Import value (US$ thousand)	First	%	Second	%	Third	%
Pepper, whole	394,560	Vietnam	32.6	Indonesia	17.5	Brazil	16.7
Pepper, crushed/ground	99,536	Germany	18.2	India	14.8	Vietnam	8.0
Capsicum	590,420	China	23.8	India	15.9	Spain	9.3
Vanilla	394,928	Madagascar	51.8	Indonesia	12.2	Papua New Guinea	8.9
Cinnamon, whole	105,580	Sri Lanka	45.0	Indonesia	21.1	China	19.9
Cinnamon, crushed/ground	22,594	Indonesia	28.7	Brazil	14.8	Netherlands	11.1
Cloves, whole and stems	115,869	Madagascar	30.4	Sri Lanka	17.3	Tanzania, U.R.	12.5
Nutmeg, mace, cardamom	204,383	Guatemala	38.8	Indonesia	24.1	Nepal	5.7
Spice seeds	207,526	India	18.2	Syria Arab Rep.	14.7	Turkey	8.7
Ginger (except preserved)	305,321	China	64.3	Thailand	12.3	Brazil	3.3
Thyme, saffron, bay leaves	105,896	Iran Islam Rep.	29.3	Spain	25.0	Turkey	12.0
Spices n.e.s. mixtures	427,268	Germany	15.9	India	13.9	Netherlands	6.9

Note: n.e.s. = not elsewhere specified.

Table 1.3. Main spice-importing countries by commodity; value and percentage share, 2004.

Spice category	Import value (US$ thousand)	First	%	Second	%	Third	%
Pepper	494,096	USA	23.1	Germany	10.9	Netherlands	5.3
Capsicum	590,420	USA	23.6	Malaysia	7.6	Germany	7.1
Vanilla	394,928	USA	51.9	France	11.3	Germany	9.3
Cinnamon	128,174	Mexico	21.0	USA	16.9	India	6.0
Cloves	115,869	Singapore	46.3	India	23.7	Malaysia	7.1
Nutmeg, mace, cardamom	204,383	Saudi Arabia	25.0	India	8.0	Netherlands	8.0
Spice seeds	207,526	USA	11.1	Germany	8.4	Malaysia	6.5
Ginger (except preserved)	305,321	Japan	41.2	USA	12.1	Pakistan	6.2
Thyme, saffron, bay leaves	105,896	Spain	20.2	USA	13.9	Italy	8.0
Spices n.e.s. mixtures	427,266	USA	13.0	Belgium	7.8	Germany	6.8

Note: n.e.s. = not elsewhere specified.

with 8.6%, followed by Madagascar 8.2%, Indonesia 7.3%, Vietnam 5.1%, Brazil 4.1%, Spain 3.1%, Guatemala and Sri Lanka 2.8%. Table 1.3 shows the rankings of the top three exporting countries of individual spices to international markets.

Developing countries, including least developed countries, supply about 55% of spices to global markets. The USA, the European Union, Japan and Singapore are among the major markets, accounting for about 64% of the world import share of spices. Germany, the Netherlands and Singapore are significant re-exporters in the spice trade.

Apart from competing for markets, developing country producers and exporters face many challenges, including that of quality issues. Spice exports are subject to strict quality standards for food safety set by the American Spice Trade Association (ASTA) and the European Spice Association (ESA). Demand is growing for high quality and processed spices. This trend for value-added products offers new business opportunities in the spice trade.

Global production of spices

Table 1.4 gives the major spice-producing areas in the world, while Table 1.5 shows the area and production of important spices in the world. Compared with many other field and horticultural crops, area and production of spices is limited. The FAO database gives the area and production of a limited number of spices only. Spices were cultivated in an area of 7587.02 thousand ha, with a production of 31,859.69 thousand t during 2005. The world export of spices during 2005 was 3592.48 thousand t and import was 3454.40 thousand t (Anon., 2007).

1.3. Major Compounds in Spices

Spices impart aroma, colour and taste to food preparations and sometimes mask undesirable odours. Volatile oils give the aroma, and oleoresins impart the taste. Aroma compounds play a significant role in the production of flavourants, which are used in the food industry to flavour, improve and increase the appeal of their products. They are classified by functional groups, e.g. alcohols, aldehydes, amines, esters, ethers, ketones, terpenes, thiols and other miscellaneous compounds. In spices, the volatile oils constitute these components (Zachariah, 1995; Menon, 2000).

In black pepper, caryophyllene-rich oils possess sweet floral odours, whereas oils

Table 1.4. Spice-producing areas.

Spices	Botanical name	Edible part(s)	Major source/origin
Ajowan	*Trachyspermum ammi* (L.) Sprague	Seed	Persia and India
Aniseed	*Pimpinella anisum* L.	Fruit	Mexico, The Netherlands, Spain
Basil	*Ocimum basilicum* L.	Sweet, leaf	France, Hungary, USA, Serbia and Montenegro
Bay leaf	*Laurus nobilis* L.	Leaf	Turkey, USA, Portugal
Cardamom	*Elettaria cardamomum* White et Mason	Fruit	India, Guatemala
Large cardamom	*Amomum subulatum* Roxb.	Fruit	India, Nepal, China
Cassia	*Cinnamomum cassia* (L.) Presl	Stem, bark	China, Indonesia, South Vietnam
Celery	*Apium graveolens* L.	Fruit	France, India
Chilli	*Capsicum frutescens* L.	Fruit	Ethiopia, India, Japan, Kenya, Mexico, Nigeria, Pakistan, Tanzania, USA
Cinnamon	*Cinnamomum verum* syn. *C. Zeylanicum*	Stem, bark	Sri Lanka, India
Clove	*Syzygium aromaticum* (L.) Merr. et Perry	Buds	Indonesia, Malaysia, Tanzania
Coriander	*Coriandrum sativum* L.	Fruit	Argentina, India, Morocco, Romania, Spain, Serbia and Montenegro
Cumin	*Cuminum cyminum* L.	Fruit	India, Iran, Lebanon
Curry leaf	*Murraya koenigii* Spreng	Leaf	India, Burma
Dill	*Anethum graveolens* L.	Fruit	India
Fennel	*Foeniculum vulgare* Mill.	Fruit	Argentina, Bulgaria, Germany, Greece, India, Lebanon
Fenugreek	*Trigonella foenum-graecum* L.	Fruit	India
Garcinia	*Garcinia cambogia*	Fruit	India, Sri Lanka
Garlic	*Allium sativum* L.	Bulb/clove	Argentina, India
Ginger	*Zingiber officinale* Rosc.	Rhizome	India, Jamaica, Nigeria, Sierra Leone
Mint	*Mentha piperita* L.	Leaf/terminal shoot	Bulgaria, Egypt, France, Germany, Greece, Morocco, Romania, Russia, UK
Mustard	*Brassica nigra* (L.) Koch	Seed	Canada, Denmark, Ethiopia, UK, India
Nutmeg	*Myristica fragrans* Houtt.	Aril/seed kernel	Grenada, Indonesia, India
Onion	*Allium cepa* L.	Bulb	Argentina, Romania, India
Oregano	*Origanum vulgare* L.	Leaf	Greece, Mexico
Paprika	*Capsicum annuum* L.	Fruit	Bulgaria, Hungary, Morocco, Portugal, Spain, Serbia and Montenegro
Parsley	*Petroselinum crispum* (Mill) Nyman ex A.W. Hill	Leaf	Belgium, Canada, France, Germany, Hungary
Black pepper	*Piper nigrum* L.	Fruit	Brazil, India, Indonesia, Malaysia, Sri Lanka, Vietnam

Continued

Table 1.4. *Continued*

Spices	Botanical name	Edible part(s)	Major source/origin
Poppy	*Papaver somniferum* L.	Seed	The Netherlands, Poland, Romania, Turkey, Russia
Rosemary	*Rosmarinus officinalis* L.	Leaf, terminal shoot	France, Spain, USA, Serbia and Montenegro
Saffron	*Crocus sativus* L.	Pistil of flower	Spain
Sage	*Salvia officinalis* L.	Leaf	Albania, Serbia and Montenegro
Star anise	*Illicium verum* Hooker fil.	Fruit	China, North Vietnam
Tamarind	*Tamarindus indica* L.	Fruit	Indonesia, Vietnam
Thyme	*Thymus vulgaris* L.	Leaf	France, Spain
Turmeric	*Curcuma longa* L.	Rhizome	China, Honduras, India, Indonesia, Jamaica
Vanilla	*Vanilla planifolia* Andrews	Fruit/beans	Indonesia, Madagascar, Mexico, India

Source: cookingsecrets.org/herbs-spices/spice-producing-areas.

Table 1.5. Area and production of important spices in the world.

Spice(s)	Area (thousand ha)	Production (thousand t)
Anise, badian, fennel, coriander	661.16	467.86
Chillies and peppers (dry)	2,004.81	2,662.73
Chillies and peppers (green)	1,725.54	24,803.01
Cinnamon (canella)	176.98	134.8
Cloves	466.08	145.18
Ginger	338.9	1,119.74
Nutmeg, mace and cardamom	222.89	74.02
Pepper (*Piper* sp.)	473.55	407.41
Vanilla	76.44	10.36
Other spices	1,440.67	2,034.58
Total	7,587.02	31,859.69

Source: FAO database (2007).

with high pinene content give turpentine-like off-odours (Lewis *et al.*, 1969). The major compounds in fresh pepper are *trans*-linalool oxide and α-terpineol, whereas dry black pepper oil contains α- and β-pinenes, d-limonene and β-caryophyllene as major components.

In cardamom, the oil has very little mono- or sesquiterpenic hydrocarbons and is dominated by oxygenated compounds, all of which are potential aroma compounds. While many of the identified compounds (alcohols, esters and aldehydes) are commonly found in many spice oils (or even volatiles of many different foods), the dominance of the ether, 1,8-cineole, and the esters, α-terpinyl and linalyl acetates in the composition make the cardamom volatiles a unique combination (Lewis *et al.*, 1966; Salzer, 1975; Korikanthimath *et al.*, 1997).

Ginger owes its characteristic organoleptic properties to two classes of constituents: the odour and the flavour of ginger are determined by the constituents of its steam-volatile oil, while the pungency is determined by non-steam-volatile components, known as the gingerols. The steam-volatile oil comprises mainly of sesquiterpene hydrocarbons, monoterpene hydrocarbons and oxygenated monoterpenes (Purseglove *et al.*, 1981). The monoterpene constituents are believed to be the most important contributors to the aroma of ginger and are more abundant in the natural oil of the fresh ('green') rhizome than in the essential oil distilled from dried ginger. Oxygenated sesquiterpenes are relatively minor constituents of the volatile oil, but appear to be significant contributors to its flavour properties. The major sesquiterpene hydrocarbon constituent of ginger oil is (–)-α-zingiberene. Australian ginger oil has a reputation for possessing a particular 'lemony' aroma, due to its high content of the isomers, neral and geranial, often collectively referred to as citral (Wohlmuth *et al.*, 2006).

Cinnamon possesses a delicate, spicy aroma, which is attributed to its volatile oil. Volatile components are present in all parts of cinnamon and cassia. They can be classified broadly into monoterpenes, sesquiterpenes and phenylpropenes (Senanayake, 1997). The oil from the stem bark contains 75% cinnamaldehdyde and 5% cinnamyl acetate, which contribute to the flavour (Angmor *et al.*, 1972; Wijesekera, 1978; Krishnamoorthy *et al.*, 1996).

The minor constituents like methyl amyl ketone, methylsalicylate, etc., are responsible for the characteristic pleasant odour of cloves. The oil is dominated by eugenol (70–85%), eugenyl acetate (15%) and *β*-caryophyllene (5–12%), which together make up 99% of the oil. *β*-Caryophyllene, which was earlier thought of as an artefact of distillation, was first reported as a constituent of the bud oil by Walter (1972).

The volatile oil of nutmeg constitutes the compounds: monoterpene hydrocarbons, 61–88%; oxygenated monoterpenes, i.e. monoterpene alcohols, monoterpene esters; aromatic ethers; sesquiterpenes, aromatic monoterpenes, alkenes, organic acids and miscellaneous compounds. Depending on the type, its flavour can vary from a sweetly spicy to a heavier taste. The oil has a clove-like, spicy, sweet, bitter taste with a terpeny, camphor-like aroma.

Among the seed spices, cumin fruits have a distinctive bitter flavour and strong, warm aroma due to their abundant essential oil content. Of this, 40–65% is cuminaldehyde (4-isopropylbenzaldehyde), the major constituent and important aroma compound, as also the bitterness compound reported in cumin. The odour is best described as penetrating, irritating, fatty and overpowering, curry-like, heavy, spicy, warm and peristent, even after drying out (Weiss, 2002). The characteristic flavour of cumin is probably due to dihydrocuminaldehyde and monoterpenes.

In the mature fruit of fennel, up to 95% of the essential oil is located in the fruit, greater amounts being found in the fully ripe fruit. Hydrodistillation yields 1.5–3.5%. Generally, anethole and fenchone are found more in the waxy and ripe fruits than in the stems and leaves (Akgül, 1986; Kruger and Hammer, 1999). Anethole has flavouring properties and is distinctly sweet, being 13 times sweeter than sugar.

As for coriander, in the unripe fruits and the vegetative parts of the plant, aliphatic aldehydes predominate in the steam-volatile oil and are responsible for the peculiar aroma. On ripening, the fruits acquire a more pleasant and sweet odour and the major constituent of the volatile oil is the monoterpene alcohol, linalool. Sotolon (also known as sotolone, caramel furanone, sugar lactone and fenugreek lactone) is a lactone and an extremely powerful aroma compound and is the major aroma and flavour component of fenugreek seeds (Mazza *et al.*, 2002).

Among the leafy spices, 45 aroma volatiles of desert parsley have been identified, with the major constituents as myristicin, apiole, *β*-phellandrene, *p*-mentha-1,3,8-triene and 4-isopropenyl-1-methylbenzene (MacLeod *et al.*, 1985). Among these, apiole in particular has a desirable parsley odour character. The leaf stems of celery show three main constituents of volatiles, e.g. apiole (about 23%), 3-butylphthalide (about 22%) and sedanolide (about 24%). The last two possess a strong characteristic celery aroma (MacLeod *et al.*, 1988). Limonene (40.5%), β-selinene (16.3%), *cis*-ocimene (12.5%) and β-caryophyllene (10.5%) are some of the volatile oil constituents present in celery leaves from Nigeria (Ehiabhi *et al.*, 2003).

The curry leaf plant is highly valued for its characteristic aroma and medicinal value (Philip, 1981). A number of leaf essential oil constituents and carbazole alkaloids have been extracted from the plant (Mallavarapu *et al.*, 1999). There are a large number of oxygenated mono- and sesquiterpenes present, e.g. *cis*-ocimene (34.1%), α-pinene (19.1%), γ-terpinene (6.7%) and β-caryophyllene (9.5%), which appear to be responsible for the intense odour associated with the stalk and flower parts of curry leaves (Onayade and Adebajo, 2000). In fresh bay leaves, 1, 8-cineole is the major component, together with α-terpinyl acetate, sabinene, α-pinene, β-pinene, β-elemene, α-terpineol, linalool and eugenol (Kilic *et al.*, 2004).

The major chemical constituents in spices are tabulated in Table 1.6.

1.4. Value Addition and New Product Development

Farm-level processing operations are the most important unit operations for value addition and product diversification of spices. It is essential that these operations ensure proper conservation of the basic qualities like aroma, flavour, pungency, colour, etc. Each of these operations enhances the quality of the produce and the value of the spice. The clean raw materials form the basis for diversified value-added products.

The first spice oil and oleoresin industry was started in 1930 in India at Calicut by a private entrepreneur. Extracts of ginger were manufactured during the Second World War. The major oils are from black pepper, cardamom, chilli seed, capsicum, paprika, clove, nutmeg, mace, cinnamon, cassia, kokkam, galangal, juniper and peppermint (Guenther, 1950). Pepper oil, ginger oil, celery seed oil, kokkam oil and peppermint are the major oils exported from India. Oleoresins exported are from black pepper, cardamom, chillies, capsicum, paprika, ginger, turmeric, white pepper, coriander, cumin, celery, fennel, fenugreek, mustard seed, garlic, clove, nutmeg, mace, cinnamon, cassia, tamarind, galangal, rosemary and curry powder oleoresins. Table 1.7 lists the value-added products from major spices.

1.5. Pharmacological aspects

Chemopreventive and anticancerous

Recent advances in our understanding at the cellular and molecular levels of carcinogenesis have led to the development of a promising new strategy for cancer prevention, that is, chemoprevention. Chemoprevention is defined as the use of specific chemical substances – natural or synthetic, or their mixtures – to suppress, retard or reverse the process of carcinogenesis. It is one of the novel approaches of controlling cancer alternative to therapy, which has some limitations and drawbacks in the treatment of patients (Stoner and Mukhtar, 1995; Khafif *et al.*, 1998; Kawamori *et al.*, 1999; Bush *et al.*, 2001; Jung *et al.*, 2005).

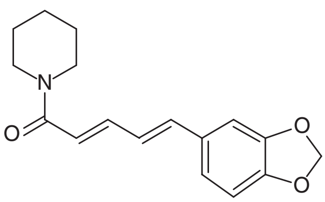
The chemopreventive and bioprotectant property of curcumin in turmeric increases cancer cells' sensitivity to certain drugs commonly used to combat cancer, rendering chemotherapy more effective. It also possesses strong antimicrobial and antioxidant activity and may slow down other serious brain diseases like multiple sclerosis and Alzheimer's disease (Lim *et al.*, 2001). The specific inhibition of HIV-1 integrase by curcumin suggests strategies for developing antiviral drugs based on curcumin as the lead compound for the development of inhibitors of HIV-1 integrase (Li *et al.*, 1993). The effect of polyacetylenes in celery leaves towards human cancer cells, their human bioavailability and their ability to reduce tumour formation in a mammalian *in vivo* model indicates that they may also provide benefits for health (Christensen and Brandt, 2006).

In star anise, the presence of a prenyl moiety in the phenylpropanoids plays an important role in antitumour-promoting activity. Hence, the prenylated phenylpropanoids might be valuable as a potential cancer chemopreventive agent (Padmashree *et al.*, 2007).

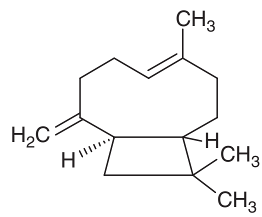
Table 1.6. Major chemical constituents in spices.

Spice crop (botanical name)	Compound and structure

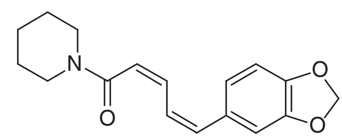
Black pepper (*Piper nigrum* L.)
Piperine, β-caryophyllene, chavicine



Piperine

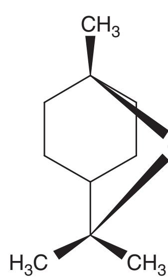


β-Caryophyllene

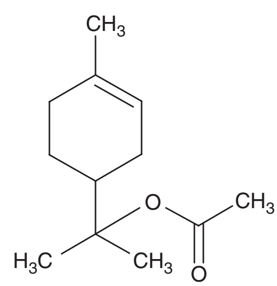


Chavicine

Small cardamom (*Elettaria cardamomum* Maton) and large cardamom (*Amomum subulatum* Roxburgh)
1,8-cineole, α-terpinyl acetate

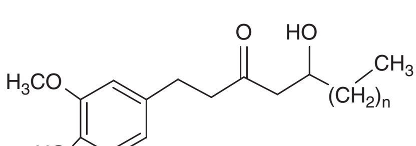


1,8-cineole

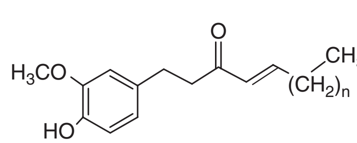


α-Terpinyl acetate

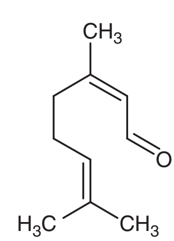
Ginger (*Zingiber officinale* Rosc.)
Gingerol, shogoal, citral, zingiberene, *ar*-curcumene



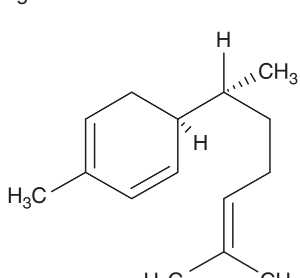
Gingerol



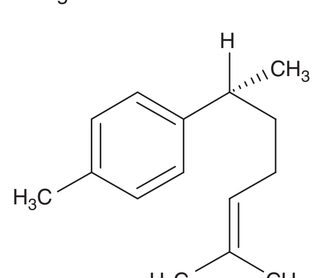
Shogaol



Citral



(–)Zingiberene



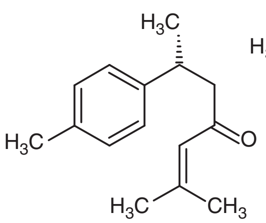
ar-Curcumene

Continued

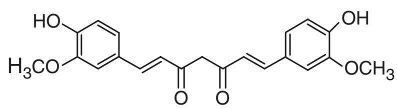
Table 1.6. *Continued*

Spice crop (botanical name)	Compound and structure

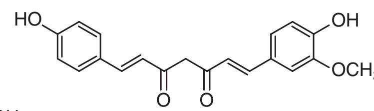
Turmeric (*Curcuma longa* L.)
ar-Turmerone, curcumin, demethoxy curcumin, *bis*-demethoxy curcumin



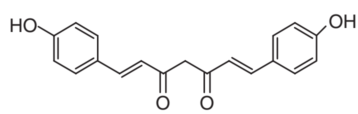
ar-Turmerone



Curcumin

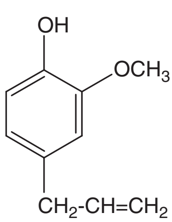


Demethoxycurcumin

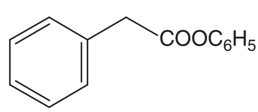


Bisdemethoxycurcumin

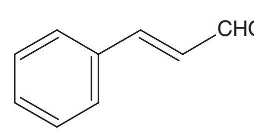
Cinnamon (*Cinnamomum verum* syn. *C. Zeylanicum*) and Cassia (*Cinnamomum cassia* (L.) Presl)
Eugenol, benzyl benzoate, cinnamaldehyde



Eugenol

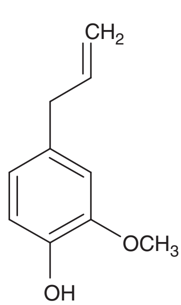


Benzyl benzoate

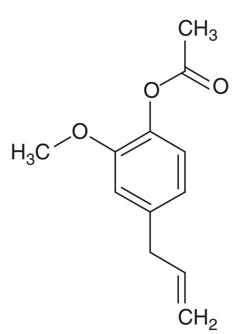


Cinnamaldehyde

Clove (*Syzygium aromaticum* (L.) Merr. et Perry)
Eugenol, eugenyl acetate



Eugenol



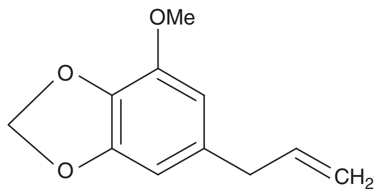
Eugenyl acetate

Continued

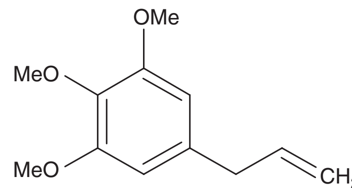
Table 1.6. *Continued*

Spice crop (botanical name)	Compound and structure

Nutmeg and mace (*Myristica fragrans* Houtt)
Myristicin, elemicin

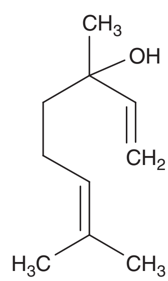


Myristicin



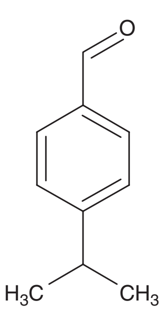
Elemicin

Coriander (*Coriandrum sativum* L.)
Linalool

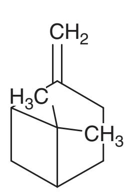


Linalool

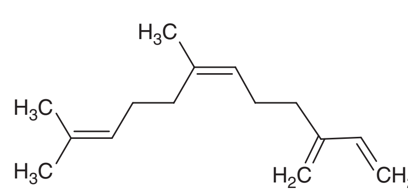
Cumin (*Cuminum cyminum* L.)
Cuminaldehyde, *β*-pinene, *cis*-*β*-farnesene



Cuminaldehyde



β-Pinene



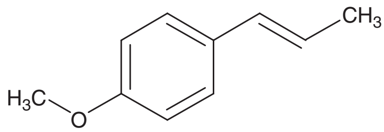
cis-β-Farnesene

Continued

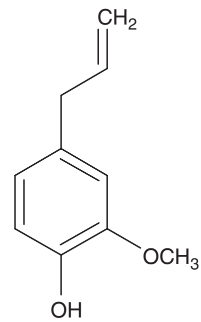
Table 1.6. *Continued*

Spice crop (botanical name)	Compound and structure

Fennel (*Foeniculum vulgare* Mill.)
Anethole, estragol

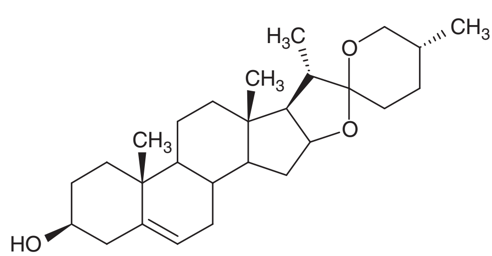


(*E*)-Anethole



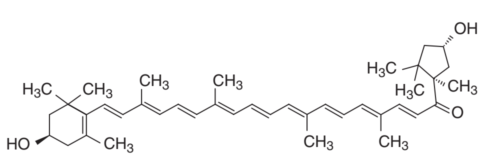
Estragol (methyl chavicol)

Fenugreek (*Trigonella foenum-graecum* L.)
Diosgenin

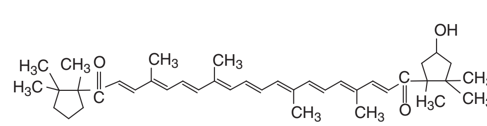


Diosgenin

Paprika (*Capsicum annum* L.)
Capsanthin, capsorubin

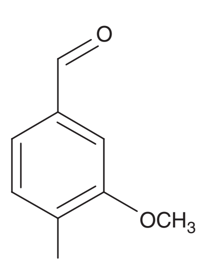


Capsanthin



Capsorubin

Vanilla (*Vanilla planifolia* Andrews)
Vanillin



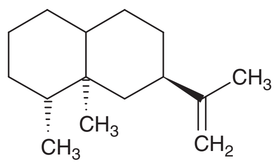
Vanillin

Continued

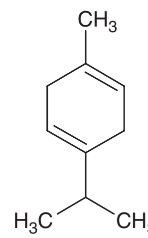
Table 1.6. *Continued*

Spice crop (botanical name)	Compound and structure

Ajowan (*Trachyspermum ammi* (L.) Sprague)
Thymol, γ-terpenene

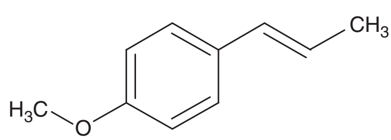


Valencene



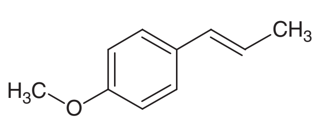
γ-Terpenene

Star anise (*Illicium verum* Hooker fil.)
(*E*)-Anethole

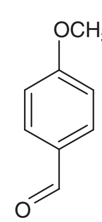


(*E*)-Anethole

Aniseed (*Pimpinella anisum* L.)
(*E*)-Anethole, anisaldehyde

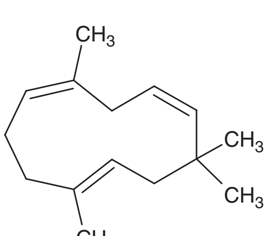


(*E*)-Anethole

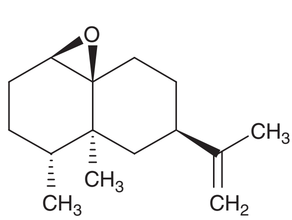


Anisaldehyde

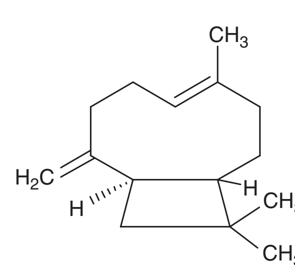
Garcinia (*Garcinia cambogia*)
α-Humelene, valencene, *β*-caryophyllene



α–Humulene



Valencene



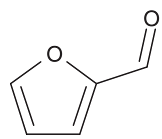
β-Caryophyllene

Continued

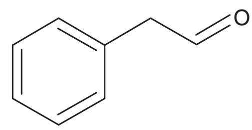
Table 1.6. *Continued*

Spice crop (botanical name)	Compound and structure

Tamarind (*Tamarindus indica* L.)
Furfural, 2-phenyl acetaldehyde

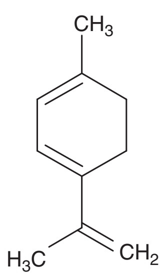


Furfural

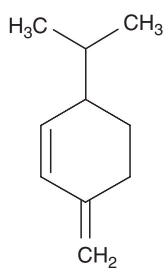


2-Phenylacetaldehyde

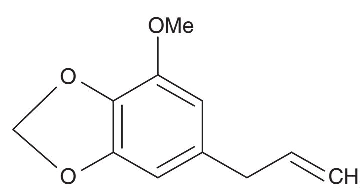
Parsley (*Petroselinum crispum* (Mill) Nyman ex A.W. Hill)
1,3,8-*p*-Menthatriene, *β*-phellandrene, myristicin



1,3,8-*p*-menthatriene

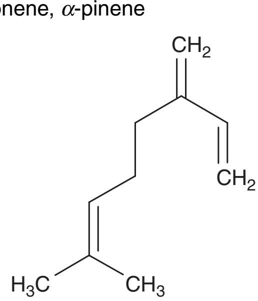


β-Phellandrene

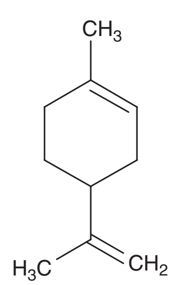


Myristicin

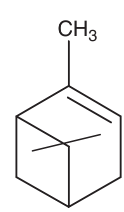
Celery (*Apium graveolens* L.)
Myrcene, limonene, *α*-pinene



Myrcene

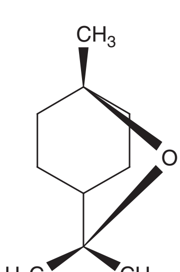


-(−) Limonene

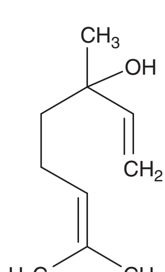


α-Pinene

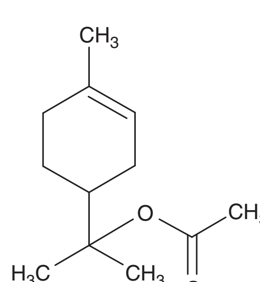
Bay leaf (*Laurus nobilis* L.)
1,8-Cineole, linalool, *α*-terpinyl acetate, methyl eugenol



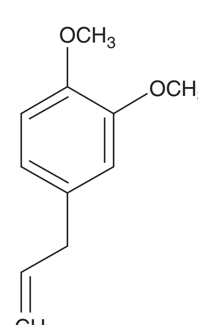
1,8-Cineole



Linalool



α-Terpinyl acetate

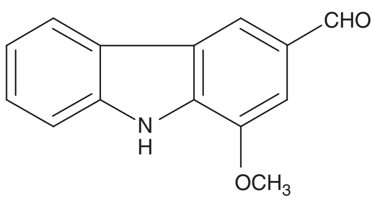


Methyl eugenol

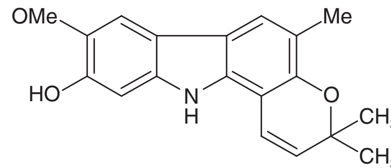
Continued

Table 1.6. *Continued*

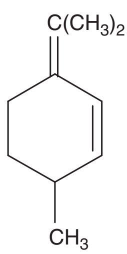
Spice crop (botanical name)	Compound and structure
Curry leaf (*Murraya koenigii* Spreng.) Murrayacine, koenigine, α-pinene, β-phellandrene	



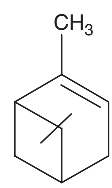
Murrayacine



Koenigine



β-Phellandrene



α-Pinene

Table 1.7. Value-added products from major spices.

Spices	Product
Black pepper	Dehydrated green pepper, freeze-dried green pepper, frozen green pepper, white pepper, green pepper in brine, pepper oil, pepper oleoresin, ground pepper, organic pepper, sterile pepper, canned tender green pepper
Cardamom (small)	Green cardamom, cardamom oil, cardamom oleoresin
Cardamom (large)	Oil, oleoresin
Ginger	Ginger oil, oleoresin, candy, preserves, vitaminized effervescent ginger powder, plain effervescent powder, starch from spent ginger, wine, beer, medicinal beverages, encapsulated ginger oil, dehydrated ginger
Turmeric	Curcuminoids, dehydrated turmeric powder, oil, oleoresin

Antioxidant

Tamarind is used traditionally as an astringent, anti-inflammatory and antidiuretic agent, and a laxative, carminative and digestive agent (Sudjaroen *et al.*, 2005; Siddhuraju, 2007). As for garcinia, the major flavouring compound is (–)-hydroxycitric acid, which is emerging as an antiobesity factor (Greenwood *et al.*, 1981; Rao and Sakariah, 1988; Jena *et al.*, 2002). However, more evidence needs to be compiled to prove its potential satisfactorily.

Apart from culinary uses, parsley is known for its anticancer, antioxidant, diuretic and laxative properties. Photosensitizing, toxic furocoumarines, including psoralen, bergaptene and isoimperatorin, have been found in parsley roots, which can induce dermatitis (Peterson *et al.*, 2006).

As a remedy for bird flu

Star anise is the industrial source of shikimic acid, a primary ingredient used to create the antiflu drug, Tamiflu, which is regarded as the most promising drug to mitigate the severity of the bird flu H5N1 strain of virus (Goodman, 2005). Currently, Tamiflu is the only drug available which may reduce the severity of bird flu (also known as avian flu).

As a bioenhancer

Piperine (1-piperoyl piperidine) in black pepper is shown to possess bioavailability-enhancing activity with various structurally and therapeutically diverse drugs. This property of piperine may be attributed to increased absorption, which may be due to alteration in membrane lipid dynamics and a change in the conformation of enzymes in the intestine (Khajuria *et al.*, 2002).

Antimicrobial

Clove bud oil has various biological activities, such as antibacterial, antifungal, antioxidant and insecticidal properties. The high level of eugenol present in the essential oil imparts strong biological and antimicrobial activity (Raghavenra *et al.*, 2006).

Curry leaves have been studied for their antifungal activity against three plant-pathogenic fungi, i.e. *Rhizoctonia solani, R. bataticola* [*Macrophomina phaseolina*] and *Helminthosporium oryzae* [*Cochliobolus miyabeanus*] (Ray and Srivastava, 2006).

Insecticidal

The volatile oil from cardamom is a potential grain protectant by killing various life stages of the stored-product insects attacking wheat, e.g. *Tetropium castaneum* and *Sitophilus zeamais Motschulsky*, via contact and fumigant action (Huang *et al.*, 2000). Cinnamaldehyde in cinnamon has strong insecticidal activity against *Acanthoscelides oblectus* and antifeedant activity against *Ceratitis capitata*, a pest causing damage to fruit crops.

Nutmeg oil also possesses strong antibacterial, antifungal and insecticidal properties. Myristicin, which imparts hallucinogenic properties, is also reported to be an effective insecticide, while the lignin types of the constituents in the nut are anticarcinogenic (Narasimhan and Dhake, 2006). Larvicidal properties, against second stage larvae of *Toxocara canis*, are also reported in mace (Nakamura *et al.*, 1988).

Curry leaves have also been proven to be effective against *Rhizopus stolonifer* [*R. stolonifer var. stolonifer*] and *Gloeosporium psidii* [*Colletotrichum coccodes*] infecting guava (Dwivedi *et al.*, 2002). Bay leaf has been used as a herbal medicine and has pharmaceutical activity which includes antibacterial, antifungal, antidiabetes and anti-inflammatory effects (Guynot *et al.*, 2003).

1.6. Conclusion

Spices produce a vast and diverse assortment of organic compounds, the great majority of which do not appear to participate directly in growth and development. These substances, traditionally referred to as secondary metabolites, assume great significance. Although noted for the complexity of chemical structures and biosynthetic pathways, the volatile and non-volatile natural products are perceived generally as biologically insignificant.

Secondary metabolites in spices have been a fertile area for chemical investigation for many years, driving the development of both analytical chemistry and of new synthetic reactions and methodologies. In recent years, there has been an emphasis on secondary metabolites in relation to dietary components, which may have a considerable impact on human health. The majority of herbs and spices constitute important bioactive secondary metabolites which possess versatile pharmacological and medicinal properties. The structure–activity relationship of these compounds is an exciting field, where molecular biology and nanotechnology can definitely play a symbiotic role.

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