

## 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'	Soluble in 1-2 vols and more of 70% alcohol, occasionally with opalescence to turbidity on dilution	Sulphur content, 15.3-29%
Allspice (Pimenta) berry oil	1.024-1.055 <sup>a</sup>	1.525-1.536	0°32' to -5°0'		Phenol content, 65-89%
Pimenta leaf oil	1.026-1.068	1.530-1.540	inactive to 5°30'	Soluble in 1-2 vols of 70% alcohol	Phenol content, 65-96%
Bay oil	0.960-0.985; <sup>a</sup> 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 <sup>a</sup>	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 (called as cinnamaldehyde), 51.8-56% Phenol (Eugenol), 14-18%
Cinnamon leaf oil	1.037-1.055''	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	Aldehyde, up to 4% Phenol. 77.3-90.5%

Cassia oil	1.055-1.070 <sup>a</sup>	1.600- 1 .606	-10 <sup>0</sup> ' to +6 <sup>0</sup> '	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 <sup>a</sup>	1.529-1.537	up to -1 <sup>0</sup> 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 <sup>a</sup>	1.531-1.538	up to -1 <sup>0</sup> 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 <sup>a</sup>	1.533-1.539	-0 <sup>0</sup> 50' to — 1 <sup>0</sup> 53'	0.9 vols or more of 70% alcohol	Eugenol. 78-93%
Ginger	0.877-0.886 <sup>a</sup> oils with lower and higher specific gravity have been observed	1.489-1.494	- 26 <sup>0</sup> 0' to - 50 <sup>0</sup> 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 <sup>0</sup> 48' to +49 <sup>0</sup> 48'		Acid number. 1.0-1.3; Ester number. 6.8-7.3
Macc	0.860-0.892	1.472-1.479	+21 <sup>0</sup> 42' to +41 <sup>0</sup> 30'		Acid number, 1.5-6.2; Ester number. 2.8-12.8
Oil of Wintergreen	1.180-1.193 <sup>a</sup>	1.535-1.536	-0 <sup>0</sup> 25' to -1 <sup>0</sup> 30'	Clearly soluble in 6-8 vols of 70'l,. alcohol	Ester number. 354-365; Ester content. caled. 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 <sup>a</sup>	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°01' +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 <sup>a</sup>	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 <sup>a</sup>	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 <sup>a</sup>	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	1.52-1.559	up to -1°50'	Soluble in 1.5-3.0 vols of 90% alcohol	
Fennel seed oil	0.965-0.977 <sup>a</sup>	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 oi Is
celery seed oil	0.872-0.891 <sup>a</sup>	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 <sup>a</sup>	1.484-1.488	+70°0' to +81°0'	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 <sup>a</sup>	1.512-1.528	-4°0' to -10°8'	4-8 vols and more of 80% alcohol	Acid number. up to 6: Ester number, I to 11, Ester number after acetylation. 4 to 20
Parsley herb oil	0.902-1.016 <sup>a</sup>	1.509-1.526	+1°16' to +4°30'	Soluble in 95% alcohol	Acid number, up to I. Ester number. 5 to 14, Ester number after acetylation, 19-68
Lemongrass oil	0.899-0.911 <sup>a</sup>	1.485-1.490	-1°10' to -3°10'	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 <sup>a</sup>	1.542-1.546	Inactive	Soluble in 1-2 vols and more of 70% alcohol	Boiling point 179°C
Sassafras oil	1.070-1.080 <sup>a</sup>	about 1.530	+2°0' to +3°38'	Soluble in 95% alcohol, 1-2 vols of 90% alcohol	Acid number, up to 1.0, Ester number. 0.5-5.0 Congealing point, 4.5-6.9°C

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<sup>a</sup> at 15°C

## 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	Cinnamomum Cassia (Lauraceae)	China, Indonesia, Vietnam, Taiwan	Cinnamaldehyde
Cinnamon oil	Cinnamomum 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

## 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	Rhizome	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

## Antioxidants isolated from herbs and spices

Spices and herbs	Systematic names	Substances and type of substances
Rosemary	<i>Rosemarinus officinalis</i>	Camosic acid, camosol, rosmarinic acid, rosmanol
Sage	<i>Salvia officinalis</i>	Camosol, camosic acid, rosmanol, rosmarinic acid
Oregano	<i>Origanum vulgare</i>	Derivatives of phenolic acids, flavonoids, tocopherols
Thyme	<i>Thymus vulgaris</i>	Thymol, carvacrol, p-cunene-2,3 diol, biphenyls, flavonoids
Ginger	<i>Zingiber officinale</i>	Gingerol-related compound, diarylheptanoids
Turmeric	<i>Curcuma domestica</i>	Curcumins
Summer savory	<i>Satureja hortensis</i>	Rosmarinic acid, camosol, carvacrol, thymol
Black pepper	<i>Piper nigrum</i>	Phenolic amides, flavonoids
Red pepper	<i>Capsicum annum</i>	Capsaicin
Chilli pepper	<i>Capsicum frutescens</i>	Capsaicin, capsaicinol
Clove	<i>Eugenia caryophyllata</i>	Eugenol, gallates
Marjoram	<i>Marjorana hortensis</i>	Flavonoids
Common balm	<i>Melissa officinalis</i>	Flavonoids
Licorice	<i>Glycyrrhiza glabra</i>	Flavonoids, licorice phenolics

## Important flavour compounds in spices

Spice	Important flavour compounds
Allspice	Eugenol, $\beta$ -caryophyllene
Anise	(E)-anethole, methyle, chavicol
Black pepper	Piperine, S-3-Carene, $\beta$ -caryophyllene
Caraway.	d-carvone, carone deri vati yes
Cardamom	$\alpha$ -terpinyl acetate. 1-8-cineule. linalool
Cinnamon, cassia	Cinnamaldehyde, eugenol
Chilli	Capsaicin, dihydro capsaicin
Clove	Eugenol, eugeneyl acetate
Coriander	d-linalool. C10-C 14-2-alkenals
Cumin	Cuminaldehyde. p-1.3-mentha-dienal
Dill	d-carvone
Fennel	(E)-anethole, fenchone
Ginger	Gingerol, Shogaol. neral. geranial
Mace	$\alpha$ -pinene, sabinene, l-terpenin -4-ol.
Mustard	Ally isothiocynate
Nutmeg	Sabinine, $\alpha$ -pinene. myristicin
Parsley	Apiol
Saffron	Safranol
Turmeric	Turmerone, Zingeberene. 1.8-cineole
Vanilla	Vanillin, p-OH-benzyl-methyl ether

## 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, linalool
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	l-menthol, menthone, menthufuran
Spear mint	l-carvone, carvone derivatives

