

Physical properties of some spice essential oils and flavourants

Spice	Specific gravity CWOC)	Refractive index (20°C)	Optical rotation (") (20°C)	Solubility characteristics	Other remarks
Asafoetida Allspice (Pimenta) berry oi I	0,906-0.973 1:024-1.055"	1.493-1.518 1.525-1.536	-9°0' to +9°18' - 0°32' to -5°0'	Soluble in 1-2 vols and more of 70% alcohol, occasionally with opalescence to turbidity on dilution	Sulphur content, IS.3-291); Phenol content, 6S-89%
Pimenta leaf oil	1.026-1.065	1,530-1,540	inactive to S030'	Soluble in 1-2 vols of 70% alcoho	Phenol content, 6S-96, *
Bay oil	0,960-0.9~S;" in oils of lower quality as low as 0.9S I 1.029-1,050'	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 Soluble in 2-2,S vols of 60% alcohol, sometimes even in 6- 6.5 vols of 50% alcohol Soluble in 2-5 vols of 70% alcohol	Phenol content S7 -60%; in oib of poor quality, as low as 40';',
Terpeneless bay oil		1,527-1.536	-0°10' to -1°20'		Phenol content, 82-9S.S%
Cardamom	0.923-0,941 "	1.462-1.467	+24°0' to +41 °	Soluble in 1-2.S vols of 70% alcohol	Acid number, up to 4; Ester number, 92-1 SO
Cardamom, wild	0.909'	1.474	+ 16°30'	Solubk in 1-2.5 vob of 70'i!.	Acid number, 1.1; Ester number, 12
Cinnamon bark. oil	1.020-1.100'	1.568-1.535	1°0' 10 2" 1 0'	akohoL occasionally opalescent to hazy Soluble in 1,5 vols or more of 70% alcohol. sometimes with opalescence or paraffin separation	Aldehyde (cab!. as cinnameldehyde), SI.X-S6lj, Phenol (Eugenol), 14-18% Adehyde, up to 4% Phenol. 77.3- 90.S%
Cinnamon leaf oil	1.037-1.05S"	1.529-1.535	1 °36' to 0°40'		

Cassia oil	1.055-1.070"	1.600-1.606	1°0' to +1°0'	Readily soluble in 1-2 vols of 70% alcohol. 2 vols of 70% alcohol with slight turbidity: freshly distilled in 2.5-3.0 vols of 60% alcohol	Aldehyde. 75-100%; Eugenol. 78-85% seldom up to 95%
Clove bud oil	1.043-1.068"	1.529-1.537	up to -1°35'	1-2 vols or more of 70% alcohol and 2.5-3 vols of 60% alcohol	Eugenol. 83-85% in exceptional cases higher
Clove stem oil	1.040-1.067"	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. 83-85% in exceptional cases higher
Clove leaf oil	1.032-1.067"	1.533-1.539	-0°50' to -1°53'	Only sparingly soluble in alcohol. Up to 7 vols of 70% alcohol for solution which is not always clear.	Eugenol. 78-93%
Ginger	0.877-0.886" oils with lower and higher specific gravity have been observed	1.489-1.494	-26°0' to -50°0' lower values observed for oils distilled from old roots stored for a long time inactive	In 10% a/c. the oils are generally but not always completely soluble. 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	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		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 isothiocyanate. <4%; boiling range at 70 mm. 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	0.860-0.880	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"	1.535-1.536	-0°25' to -1°30'	Clearly soluble in 68 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"	1.537-1.551	+1°J' to +3°S31	Most oils not completely soluble in 10 vols of 95% alcohol. Occasionally soluble in 1-2 vols or more of 95% alcohol Not readily soluble in alcohol, usually soluble in 10-15 vols of alc; soluble in 3-10 vols or 9/10 alcohol	Acid number, 12.0-111.X; Carbonyl number, 11'x'-1S.I; Iodine number, S9.9-66.~
Pepper oil	0.8n-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 or 9/10 alcohol	Acid number, up to 1.1 Ester number, O.S to 6.S Ester number al'ter acetylation, I ~~~~A; Phellandrene test, usually strongly positive Congealing point, +14-+IX"
Star anise	0.98-0.00	1.553-1.557	up to -2°; sometimes up to 0°361	Soluble in 1.5-3.0 vols of 90% alcohol	
Ajowan oil	0.910-0.930"	1.498-1.504	up to 5°01	Soluble in 1-2 vols and more of 80% alcohol	Phenols, 4S.0-S7.0%
Coriander	0.870-0.885"	1.463-1.471	+8°(Y 10 + 130(Y	Soluble in 2-3 vols of 70% alcohol	Acid number, up to S.O; Ester number, 3.0-22.7
Dill	0.89S-0.91S"	1.481-1.491	+70°W to +8°W	Soluble in 4-9 vols of XO% alcohol	Carvone content, 40-60', 1,
Anise oil	0.980-0.990	1.55-1.559	up to -10SCY	Soluble in 1.5-3.0 vols of 90% alcohol	
Fennel seed oil	0.965-0.977"	1.528-1.539	+11°01 to +24°CY	Soluble in S-8 vols of 80% alcohol and in 0.5 vols of 90% alcohol	Congealing point, not below So, and as high as 10° in good oi Is
('cle',) seed oil	o.xn O.X') I"	1-IXO1-IX-1	+(S'SY to +7(,"SII	Turbid in 'O'k alcohol	Saponification number, 2S.I-47.6

Appendix (continued)

Spice	Specific gravity (20°C)	Refractive index (20°C)	Optical rotation (°) (20°C)	Solubility characteristics	Other remarks
Onion	1.047-1.09X"	1.537-1.559	+1"J' to +3"53I	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.X; Carbonyl number, 9.8.-15.1; Iodine number, 59.9-66.2
Pepper oi I	0.873-0.916	1.480-1.499	-1(fOI +3°	Not readily soluble in alcohol, usually soluble in 10-15 vols of alc; soluble in 3-10 vols or 95% alcohol	Al.:id number, up to 1.1 Ester number, 0.5 to 6.5 Ester number al'tcr acctylation, 12-22.4; Phdlandrene test, usually strongly positive Congealing point, +14--+18"
Star anise	0.98-0.00	1.553-1.557	up to -2°; sometimes up to 0°361	Soluble in 1.5-3.0 vols of 90'Y" alcohol	
Ajowan oil	0.910-0.930"	1.498-1.504	up to SOOI	Soluble in 1-2 vols and more of 80% alcohol	Phenols, 45.0-57.0%
Coriander	0.870-0.885"	1.463-1.471	+8°01 10 + 13°CY	Soluble in 2-3 vols of 70% alcohol	Al.:id number, up to 5.0; Ester number, 3.0-22.7
Dill	0.895-0.915"	1.481-1.491	+ 70"0' to +X2"0'	Soluble in 4-9 vols of 80% alcohol	Carvone I.:ontent, 40-60'j,
Anise oil	0.980-0.990	1.552-1.559	up to - 1°501	Soluble in 1.5-3.0 vols of 90% alcohol	
Fennel seed oil	0.965-0.977"	1.528-1.539	+11°01 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
Cclny sced oil	o.xn O.X') I"	1.4XO 1.4X4	+(8'5.\' to + 7h"51'	Turbid in '0';" alcohol	Saponification 11111ul1cr, 25.1--47.6

Caraway seed oil	0.907-0.919"	IAR4-IARR	+70°0' to +RI°0'	Seldom soluble in 70% alcohol. soluble in 2-10 vols of RO% alc.. clearly soluble in equal vols of 90% alcohol 4-R vols and more of RO% alcohol	Carvone content. 50.0-60.0%
Parsley seed oil	1.043-1.110"	1.512-1.52R	-4°0' 10 -- I () "W		Acid number. up to 6: Ester number, I to II , Ester number after acetylation. 4 to 20 Acid number, up to I. Ester number. 5 to 14, Ester number after acetylation, 19-68
Parsley herb oil	0.902-1.016"	1.509-1.526	+1016' to +4030'	Soluble in 95% alcohol	Aldehyde content. 71.8-79.1 %
Lemongrass oil	0.899-0.911"	IAR5-IA90	-1010' 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	
Bitter almond oil	" 1.050"	1.542-1.546	inactive	Soluble in 1-2 vols and n)(rc of 70% alcohol	Boiling point 179°{'
Sassafras oi l	1.(070-1.0RO"	about 1.530	+2°0' to +3°3R'	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

Table 3.1 Continued

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

T~ Major essential oils - their production and adulterants

Essential oil	Origin	Major countries	Adulterants employed
Bergamot oil	<i>Citrus auranticu</i> (Rutaceae)	Italy. Ivory Coast. Brazil Argentina, Spain, Russia	synthetic linalool and linalyl acetate: orange and lime terpenes
Cassia oil	<i>Ci/lamOnU</i> (Lauraceae)	China, Indonesia, Vietnam, Taiwan	cinnamaldehyde
Cinnamon oil	<i>Cin/lamon</i> (Lauraceae)	Sri Lanka. India	leaf oil to bark oil and cinnamaldehyde
Clove leaf oil	<i>Eugenia caryophyll</i> (Myritaceae)	Madagascar. Indonesia, Tanzania, Brazil. Sri Lanka	clove stem oil
Clove bud oil	<i>Eugenia Ca/Top/n</i> (Myritaceae)	Indonesia. Madagascar	clove stem oil. leaf oil. eugenol. and stem oil terpenes
Coriander oil	<i>Corialldru</i> (Umbelliferae)	Russia	synthetic linalool
Commint oil	<i>Mentha III'ensis</i> (Labiatae)	China, Brazil. India. Paraguay. Taiwan. Thailand. North Korea. Japan	not a commercially attractive proposition
Dill oil	<i>An et IIIm graveo/ens</i> (Umbelliferae)	US. Hungary. Bulgaria, Russia Egypt	distilled orange terpenes
Eucalyptus oil	<i>Eucalyptus globus</i> (Myrtaceae)	Portugal. S. Africa. Spain, China. India. Austria. Paraguay	
Garlic oil	<i>Allium sativu</i> (Liliaceae)	Mexico. Italy. Egypt	nature identical raw materials
Ginger oil	<i>Zingiber l!fficina/e</i> (Zingiberaceae)	China, India	not often adulterated
Grapefruit	<i>Citrus paradisi</i> (Rutaceae)	Brazil. US, Israel. Argentina. New Zealand	orange terpenes
Lemon oil	<i>Citrus liIIIo/l</i> (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 Portugal
Laurel	Leaf	Turkey
Marjoram (sweet)	Leaf	Chile. France. Lebanon. Mexico. Peru Bulgaria, Egypt. France. Germany. Greece. Morocco, Romania. Russia, UK
Mint	Leaf, terminal shoot	Canada, Denmark. Ethiopia. UK
Mustard	Seed	Grenada. Indonesia
Nutmeg	Bulb	Argentina, Romania
Onion	Leaf	Greece. Mexico
Oregano	Fruit	Bulgaria, Hungary. Morocco, Portugal Spain. Yugoslavia
Paprika		
Parsley Black	Leaf	Belgium, Canada, France, Germany. Hungary
pepper	Fruit	Brazil, India. Indonesia, Malaysia. Sri Lanka The Netherlands. Poland. Romania. Turkey. Russia
Poppy	Seed	France, Spain, USA. Yugoslavia
Rosemary	Leaf, terminal shoot	
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>Rosellarinus officinalis</i>	Camosic acid, camosol, rosemarinic acid, rosmanol
Sage	<i>Sall'ia officinalis</i>	Camosol, camosic acid, rosmanol, rosmarinic acid
Oregano	<i>Origanull \ulgare</i>	Derivati\es of phenolic acids, flavonoids, tocopherols
Thyme	<i>ThYllus l'ulgaris</i>	Thymol, carvacrol, p-cunene-2,3diol, biphehyls, flavonoids
Ginger	<i>Zingiber officinale</i>	Gingerol-related compound, diarylheptanoids
Turmeric	<i>Curculla domestica</i>	Curcumins
Summer savory	<i>SaTllreja llOrtensis</i>	Rosemarinic acid, camosol, carvacrol, thymol
Black pepper	<i>Piper lligrum Capsiculll annum Capsiculll</i>	Phenolic amides, flavonides
Red pepper	<i>frlltescence Eugellia carvophyllata</i>	Capsaicin, capsaicinol
Chilli pepper	<i>llOrtensis Melissa</i>	Eugenol, gallates
Clove	<i>o,fficialis Glycyrrhi:::a glabra</i>	Flavonoids
Marjoram		Flavonoids
Common balm		Flavonoids, licorice phenolics
Licorice		

Important flavour compounds in spices

Spice	Important flavour compounds
Allspice	Eugenol, <i>l</i> -caryophyllene (E)-anethole,
Anise	methyl chavicol Piperine, S-3-Carene, J-
Black pepper	caryophyllene d-carvone. carone deri vati yes
Caraway.	a-terpinyl acetate. 1-8-cineole. linalool
Cardamom	Cinnamaldehyde. eugenol
Cinnamon, cassia	Capsaicin, dihydro capsaicin Eugenol.
Chilli	eugeneyl acetate
Clove	d-linalool. C I O-C 14-2-alkenals
Coriander Cumin	Cuminaldehyde. p-1.3-mentha-dienal d-
Dill	carvone
Fennel	(E)-anethole, fenchone
Ginger	Gingerol, Shogaol. neral. geranial a-pinene,
Mace	sabinene, l-terpenin-4-ol. Allyl isothiocyanate
Mustard Nutmeg	Sabinine, a-pinene. myristic in
Parsley	Apiol
Saffron Turmeric	Safranol
Vanilla	Turmerone, Zingiberene. 1.8-cineole Vanillin, p-OH-benzyl-methyl ether

Important flavour compounds in a few culinary herbal spices

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

